Fermi National Accelerator Laboratory

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NK Muon Beam

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General Description of NK

Experiment 782 will be a fixed target experiment to make direct observations of muon events in the Tohoku Bubble Chamber at its present location in Lab F. It will study muon induced production of vector mesons, strange and charm particles and structure functions for a wide range of Q^2 down to a Q^2 of approximately 0.1 GeV^2 with low systematic bias. In addition, it will be possible to study and compare neutrino and muon interactions in the same 4π detector as well as to study the EMC effect. In the previous running periods the Tohoku Bubble Chamber was employed in neutrino experiments. It sat in the NC Neutrino beam downstream of the Neutrino Area berm specifically designed to filter out non-neutrinos. For Experiment 782, the task of the new NK Muon Beam will be to transport an acceptable quality and intensity muon beam to the Tohoku Bubble Chamber to accomplish its physics goals while <u>minimizing</u> the cost. This memo will describe the new NK Muon Beam and the changes necessary to the existing Neutrino Area to make Experiment 782 possible.

The NK Muon Beam will be a modified version of the existing NT beam line (see figure 1). The decision to employ a modified version of the NT beam line was made based on considerations of cost and availability of the beam line. Preliminary studies considered use of other beam lines, e.g., the NW beam line, and even of moving the bubble chamber with its superconducting coils but were rejected for reasons such as cost, personnel limitations, and potential conflicts with other users.

The NK beam line will be very similar to the existing NT beam line up to Enclosure NEB. The most significant difference upstream of Enclosure NEB will be in the splitting off of the "mini-pings" down the NE channel in Switchyard and then down the NT/NK line at Enclosure N01, also known as "Neuhall". In the past, NE took only slow spill. Every effort was made to prevent the accidental transmission of the fast spill down the NE beam line. There will be no fast spill down the NC line during the next running period. Instead, mini-pings, low intensity (approximately 1 x 10^{11} protons/spill divided into 6 spills of about 3 msec each) fast spills will be delivered by the Switchyard down the NE for the next run while

Experiment 782 takes data. In addition, slow spill will be needed for the users of the NT (the NE serves as the common beam line for NT, NK and NE users until NT/NK is split off from NE at the downstream end of Enclosure N01) and the NE beam lines. The NT beam will serve as a calibration beam for the ZEUS detector (at HERA). NE will serve Experiment 690 at Lab G. The actual switching between the NK and NE will be done by a switching magnet.

In a meeting of 9 March 1988 with Linda Stutte, Sam Childress and myself, we discussed the possibility of using "PH130", orbit bump magnet, type magnet rather than the NE1W, a 4-4-30, or the proposed new Visser magnet as the switching magnet. PH130, which might also be called a "5.125-1.5-40" in the Fermilab nomenclature, had been employed in the 1987-1988 fixed target run in the NC beam to help control the fast spill. It was located at the upstream end of Enclosure N01. Since there will be no fast spill neutrino experiments for the 1989 run PH130 will be available for reuse assuming it is suitable for the mini-pings. It might be used in the NE beam to handle the mini-pings as they come out of switchyard. An appropriate magnet is required at this point since the slow spill and the mini-pings will take different trajectories through the switchyard but must be on the same trajectory as it traverses through most of Enclosure N01. The Mechanical Group has already been alerted to the need to provide space for another magnet at the upstream end of Enclosure N01 in the NE beam line. If we had another magnet of the PH130 type, it might be used as the switching magnet between the NE and the NT/NK beam lines. The specifications for the 5.125-1.5-40 indicates that it has a design field of 3.34 KG at 63 amps and 11 volts and has 40 inches of magnet steel. This would make PH130's $\int B \cdot dl$ comparable to a 4-4-30 which has a design field of 4 KG at 180 amps and 50 volts and has 30 inches of magnet steel. Since a 4-4-30 is known to be capable of switching the beam between the holes of the NE4D two hole Lambertson dipole, it would seem that by relocating a second PH130 type magnet to a position near the Neuhall septa we have the required switching magnet if they can be made to ramp properly. To this end a search of "Maglist" Research Division magnet inventory list was made. Among the available magnets is a magnet identified as a 5.125-2-40, FRD11501. This class of magnets in the "Maglist" is identified as a "shimmed orbit bump" magnet. Investigation is now under way to determine if this magnet is truly available and can be employed for our downstream Enclosure N01 switching needs. Also under investigation is the power supply/control units needed to control the "shimmed orbit bump" magnet. If the power supply/control units are not available in good working order, the other alternatives mentioned above may be a more attractive choice.

On 27 July 1987 of the run that just ended, the septa in the NE beam at Enclosure N01 developed vacuum problems and was inoperative for a time. The 4-4-30, NE1W, was therefore used as a switch. It sent beam down the NE beam line with it set to 140 (corresponding to about 3.5 KG or 2.7 KG-m) and sent beam down the NT/NH beam line with it set to 40. Since a 4-4-30 is a solid iron magnet, given the expected ramping requirements for a magnet to switch between NK and NE beam, a 4-4-30 will be too slow. Studies carried out by the group led by Aga Visser indicate that even a specially modified "4-4-30" with a reduced aperture of 2.5 x 2.5 inches and reduced magnet iron requires at least 500 msec. to ramp up to or down from 4 KG field to 0. Thus, the switch between NK and NE will have to be done by a new magnet. NE1W will also be retained to help with the fine tune of the NK and NE and for the case where NK is off and NT and NE are running using the septa to provide the NT/NE split. As before, NE1W will also serve as a backup to the septa when NT and NE beams are required. It should be kept in mind that NE1W will have NK/NT and NE passing through it so when it is on it will affect NK/NT as well as NE. The "new" magnet to split off the NK might be an exiting 5.125-2-40 "bump magnet". As mentioned above, an unused 5.125-2-40 has been located. It will be tested by the Electrical Group to see if its characteristics are suitable with the characteristics of the mini-pings provided by Mike Harrison of Switchyard. These characteristics call for mini-pings which start approximately 50 msec. from the end of slow spill, a mini-ping of about 3 msec. duration, followed by approximately 150 msec. until the start of the next part of the slow spill. However, it is the belief of Aga Visser of the Electrical Group that the 5.125-2-40 will probably be not entirely suitable. Measurements of the 5.125-2-40 ramp characteristics should be available sometime in the autumn of 1988.

Since 5.125-2-40 is not expected to be good enough, a totally new but inexpensive magnet has been designed by Aga Visser. It uses many components already in hand and is designed to match the characteristics specified by Mike Harrison. A prototype magnet and power supply is being built by the electrical group. It will probably be the magnet that will be employed to do the actual switching between the NT/NK and the NE during the next run. I am informed by Aga Visser that Switchyard has expressed interest in using his magnet should it work as designed.

Whatever magnets are used in Enclosure N01 for the switching between NT/NK and NE during the mini-ping extraction, the downstream one should be placed as close as possible to the existing electrostatic septa in Enclosure N01. By placing the magnet in this location, the differences in the beam angles between the electrostatic septa (NT and NE getting slow spill) and the switching magnet operation (NT/NK getting mini-pings, NE getting slow spill) modes will be minimized. A switching magnet which is further upstream will have the advantage of requiring smaller change in fields between the NE and NT/NK values. However, by increasing the distance between the septa and the switching magnet, a greater amount of angular change in the beams incident on NE4D Lambertson will result between the septa and the switching magnet mode of operation. A greater change in the angles will make life more difficult downstream. We were able to operate the NE/NT magnets in Enclosure NE4 in a "DC" mode and successfully transmit beam to the next enclosure. This "DC" mode of operation was made possible by a judicious rotation of the NE4D Lambertson. The rotation made the divergent NE and NT beams coming into NE4D horizontally parallel again since it steered only the NE beam. If there were significant differences in the angles between the septa and switching magnet modes, the "DC" operation of the magnets in Enclosure NE4 will no longer be possible. We would have to make independent horizontal corrections for the NE and NK at NE4 since the split between NE and NT/NK is horizontal. The only horizontal device in Enclosure NE4 for the NE and NT/NK beams is NE4E which consists of a pair of 4-2-240s. While 4-2-240s can be ramped and the amount of change can be expected to be relatively small, I would prefer not to have to employ these dipoles to accommodate six pings and five to seven slow spills during a single flattop. No studies have been made as of this time on how long it would take this pair of 4-2-240's to change levels to make the two beams parallel.

More specifically, the operating mode of the switching magnet adjacent to the septa for the mini-pings is envisioned to be as follows. NE1W will be operated at approximately 2.007 KG (east bend) for a 800 GeV/c beam. This will aim the beam at the NE aperture of the NE4D two hole

Lambertson magnet with the septa moved out and the switching magnet for the NK beam turned off. Assuming that the new 2.125' long Visser magnet is used to switch the mini-pings down the NT/NK line and that it is located just downstream of the second septa (I assumed 2' gap between the septum and the Visser magnet) in Enclosure N01, it must be operated at approximately 2.6056 KG (east bend) for a 800 GeV/c mini-ping. The Visser magnet will be on only during the gaps in the slow spill when the mini-pings are extracted. Operating at this value, the Visser magnet will aim the mini-pings into the field free aperture of the NE4D Lambertson magnet (starting at Z = 7491.0174). When NE and NT is in operation, the Visser magnet will be off during the entire spill. The remotely controllable electrostatic septa will be brought back into the beam and the switching will be accomplished with its help. During the running period that ended in 1988, the size of the beam at NE1WC3, located between NE1DW-2 and the upstream septum, was approximately 1 cm high and about 1.5 cm wide full width at the base (see hardcopies in the NT/NH Log, page 228, 27 July 1987). Since the aperture of the Visser magnet is 2" vertical and 2.06" horizontal (full width), if the beam provided by Switchyard is similar in size to that given during the previous run the Visser magnet can be kept in place regardless of whether there is mini-pings or not.

It should be noted that it will not be possible to send both slow spill and mini-pings down the NT/NK during the same accelerator cycle unless the NE beam is totally deprived of any beam and all is aimed down the NT/NK. This should not be a problem since there are no plans at the moment which require that both slow spill and mini-pings be sent down the NT/NK during the same accelerator cycle.

There will probably be a changes in the upstream end of the NT/NK beam with the beam monitoring instrumentation. The expected changes are due to the significant differences between the characteristics of the mini-pings and the slow spill. Given the exiting wire chambers and intensity monitors, we may not be able to monitor the mini-pings and the slow spill on the same device during the same accelerator cycle. Since there will be different users for the mini-pings and the slow spill and since they will be running during the same accelerator cycle, it will be important to provide independent readout. Preliminary study by the Fermilab Research Division's Instrumentation Group seems to indicate that we will have to have separate devices. This will add cost and increase complexity in that duplication of instrumentation will be required with the instrumentation set to detect different type of spills. Aside from the cost and the complexity factor there will be another problem in Enclosure NE4. Enclosure NE4 is a very cramped area for the NT/NK/NE beam. Space is at a premium there. Another wire chamber is needed upstream of the NE4D Lambertson magnet to independently monitor the mini-pings and thus more space will be required. It may be necessary to shorten the maximum lengths of the tungsten forming the tungsten pyramid, NE4TNG, shift the Lambertson magnet downstream slightly and install a new wire chamber and intensity monitor. The tungsten pyramid was installed to provide NE beam intensity control and does not affect the NT/NK beams. Discussions with David Christian of Experiment 690 indicates that there will be a need for the tungsten pyramid. Calculations are being done by him to try to determine what will be the maximum attenuation required by the pyramid. He is aware of the need to provide additional space at the entrance of Enclosure NE4 for the new instrumentation. In other areas besides Enclosure NE4 the problem with space is not as acute. We cannot avoid the cost or the complexity factor but there will be space.

There may also have to be some modifications to the the target for the NT/NK beam in Enclosure NE8. Depending upon the amount of Be absorber employed ending 1.5' upstream of NKBW1-1, the first 20' dipole in Enclosure NEB, the "HALO" Monte Carlo runs make the following predictions about the yields at the Tohoku Bubble Chamber (see table below). The leftmost column below gives the total number of muons reaching a vertical stripe 3 cm (full width) wide at the center of the bubble chamber assuming 0 degree production angle. The experimental requirement is for 500 non-halo muons per mini-ping within the vertical stripe. Since there will be 6 mini-pings per cycle, if the yield is as good as predicted by "HALO", we will require about 3 $\times 10^{10}$ protons incident on the target in Enclosure NE8. (For all of the calculations in the table below, have assumed the following gradients for the quads: NK9Q1 = 1.3323 KG/in, NK9Q2 = -1.1899 KG/in, NKAQ = 1.74847 KG/in, NKBQ1 = -3.66938 KG/in, NKBQ2 = 4.22768 KG/in, and NKCQ = 1.57949 KG/in. These quad values assume that the beam in Enclosures NE9 and NEA is tuned for 200 GeV/c, while the beam starting with Enclosure NEB will be tuned for 196.21833 GeV/c. The positions of the magnets are documented in the NKBS1 "BSHEET" of 1435, 8 June 1988 and assume the use of four 8Q32's as NKCQ.) In making these calculations I assumed 800 GeV/c primary protons producing a spot on the NT/NK target that was 0.2 x 0.2 inches half width on a one interaction length target.

Be length	hadron attenuation	μ/halo	μ/10^{11} protons on target
20.00'	3.12×10^{-7}	1.63	11.1 K
21.50'	1.01×10^{-7}	1.77	11.0 K
24.50'	1.07×10^{-8}	1.42	9.7 K
27.99'	7.85×10^{-10}	1.31	9.1 K

It is important to keep in mind that we have been informed by the Switchyard experts that it will be difficult for them to provide mini-pings with intensities much below 1×10^{11} protons/spill. Thus, if the intensity is too high for the NK users with 1×10^{11} protons/spill the beam line must be designed to reduce the intensity to the required level. One possible way to reduce the intensity is to use a shorter target or different target of the same length. Another question which must be resolved is that of target cooling. Some calculations done earlier by Anthony Malensek and independently by Nkikolai Mokhov for 2×10^{11} protons/accelerator cycle on a spot about 0.2 cm by 0.2 cm indicated that cooling of the target may be needed. Work will be done soon to investigate what will be needed at 1×10^{11} protons on target and what will happen if the spot on target is larger. If changing the target and or spot size proves to be unacceptable, another possibility will be to change the production angle of the beam using the dipole NT8UE/NK8UE. Among the factors which will determine the method of beam intensity reduction chosen will be on factors such as the expected halo/muon ratio and reliability. HALO is not equipped to handle non-zero degree production angle. Changing the production angle also means that the locations at which the non-interacting proton beam and the off momentum secondary beam are lost varies depending upon the field of NT8UE/NK8UE dipole. This change will probably influence the halo/muon ratio. Only tests with beam will probably determine what is the best scheme to employ to minimize the halo/muon ratio.

Another possible way to reduce the beam intensity will be to employ collimators that already exist in Enclosures NE9 and NEA, these are NK9CH, NK9CV and NKACH. This possibility will be investigated but I do not expect favorable results. Anything unneeded that is inserted into the beam tends to increase the halo/muon ratio. Partial insertion of steel jaws of collimators will probably also increase this ratio. However, HALO studies will be done to check if this expectations is correct. If the halo/muon ratio is not changed by this method of intensity reduction, we will have an additional method of beam intensity reduction.

The differences with the existing beam starting with Enclosure NEB will be much more extensive. For the 1989 run it is expected that the NK beam will take about 2/3 of the running time and NT will be given the remainder of the running time. It is also expected that the change from the NK to NT user and back will occur a number of times during the running period. Thus, we must maintain the ability of the NT beam to be given beam with a minimum of changeover time and effort while building the new NK beam.

Until now we have had the capability of splitting off the NH beam from the NT in Enclosure NEB. In the "low momenta" configuration, which employed only three of the five 5-1.5-240 dipoles that could make up NTBW1/NHBW1, it was possible to switch part of the spill to the NH and another part to NT by ramping this dipole string to the correct values. The unused pair of 5-1.5-240s were there in case either the NT or NH beam had to operate in the "high momenta" configuration when it was not possible to switch from NH to NT on the same spill. When not in use the unused 5-1.5-240s were kept in the Enclosure but out of the beam. For the 1989 running period the NH beam will not be used according to present scheduling. Among the magnets that will be taken for other uses will be the dipole string NHFW, the NTBW1-4/NHBW1-4 and NTBW1-5/NHBW1-5 dipoles, NHBV trim, and the NHBQ1 and NHBQ2 quads. In Enclosure NEB the NHBV trim, the NHBQ1 and NHBQ2 quads, the forth and fifth 5-1.5-240s that were unused during the 1987-88 run, and their associated power supplies will be employed in Enclosure NEB for the NK beam as NKBV, NKBQ1, NKBQ2, NKBW2-1 and NKBW2-2 respectively.

Because the differences in the magnitude of the bends formed by the NTBW1/NKBW1 string will be too large to fit both NK and NT beams within the magnet aperture, it will be necessary to move at least the downstream components of NTBW1/NKBW1 depending on whether the NT or NK beam is being used. This differs from the 1987-1988 running period where the magnitude of the bends for NT and NH were similar enough that it was possible to send low momenta beam to both the NT and NH beams by aligning the NTBW1/NHBW1 dipoles in a compromise position and varying the field in this dipole string. By the time the NK beam reaches the downstream end of NEB the separation between NT and NK will be sufficient to place NKBW2-1 and NKBW2-2 adjacent to the NTBW2-1 and NTBW2-2 that are already in place. Thus, when the time arrive to switch from NT to NK or vice versa, it will be necessary to move the dipoles which serve as NTBW1/NKBW1 to their correct positions. To accomplish the move of the NTBW1/NKBW1, it will be necessary to build new stands to permit the greater range of horizontal traverse required to go from one position to the other. These stands will be operable remotely so that access will not be needed to move these magnets from one position to the other. It will not be necessary to move any of the quads, trims, NTBW2 or NKBW2 to make this switch. However, it may be necessary to build modified magnet stands as the floor of Enclosure NEB is not all at the same level. The power supply for NTBW2 and NKBW2 must be shared since there is inadequate space for an additional power supply. However, since the available power supply cannot power both NTBW2 and NKBW2 at the same time due to the total resistance a switch will be installed. This switch will send power to either NTBW2 or NKBW2 but not both. The switch will be remotely controllable to allow changes to take place without an access.

In addition, it will be necessary to insert or remove a hadron filter at the upstream end of Enclosure NEB depending on whether NK or NT is to run. At the moment plans call for 21.5 feet of Be to be used to provide a hadron attenuation of approximately 1×10^{-7}. This be will be installed just upstream (starting with HALO run BCHALO3 of 14 June 1988) of the first 5-1.5-240 dipole, NKBW1-1, in Enclosure NEB. If 21.5 feet of Be is inadequate to achieve the desired muon/hadron ratio the stand to support the Be is being designed so that additional Be can easily be added to gain the desired result. The table given earlier gave the expected yields and muon/hadron ratios for various amounts of Be. The Be will be encapsulated in such a way as to minimize the potential handling hazard of this material when the time comes to insert or remove it from the beam. A check with Radiation Safety approved the use of the Be without Fe shielding around it at the expected intensities of the NK beam. However, Radiation Safety will require that method be devised which will assure that no Be can be removed without their knowledge. A design to satisfy this requirement will be part of the design criterion for the filter and its stand. Further consideration which must be taken into account has to do with the fact that the Be filter is in Enclosure NEB. Any access is required to adjust the filter length or position is likely to affect the operation of the NE users at Lab G (Experiment 690) since the NE beam also passes through Enclosure NEB. Therefore, another design criterion is to devise a Be filter and associated stand which will minimize the effort required to make changes in length. The stand for the filter will be made remotely controllable. Finally in regards to the Be filter, given the pieces of Fermilab owned Be available to us, the filter will have to be made up of series of stacks of Be pieces. Since the Be pieces are relatively small there will be many cracks between Be pieces in the direction of the beam travel. To minimize the amount of cracks a hadron might traverse, we will stagger the pieces in such a way to prevent continuous cracks through the length of the filter. Further, we will employ Jorge Morfin's suggestion of slightly cocking the Be filter relative to the beam both in the horizontal and vertical plane. By cocking the Be filter, there will be even smaller chance for a hadron to traverse a full length of a crack between the Be pieces. The filter will be made large enough cross sectionally so that there will not be any problems about beam leaving the Be filter before its full length is traversed and yet still make it all the way down to the bubble chamber.

In deciding where to place the magnets for the NK beam within NEB, considerations had to be given for momentum tagging of the beam. To permit this it was necessary to provide space upstream of the final bend string in the NK beam, NKBW2, consisting of two 5-1.5-240's with a total bend of 28.16 mr. Since space in NEB is limited and since clearances must be reserved for NT beam which passes adjacent to the NK beam, only about 29.5 feet of space could be given between the NKBQ2 quad and the start of NKBW2. Immediately downstream of NKBW2 dipole string and NKBV trim room has been left within Enclosure NEB for at least one set of momentum tagging scintillator or chamber. The second part of the downstream set could be placed in New Enclosure NKC although it will have to be large enough to cover an area 8.244 inches in diameter (the size of the 8Q32 bore).

In addition to the repositioning of the magnets within Enclosure NEB, a substantial modifications had to be done to the enclosure itself. Enclosure

NEB contains within it the remnants of old Enclosure 109. Much of the utilities for NEB were attached to the columns that formed the walls of 109. Among these are LCW pipes, power and lighting, and cable trays. Unfortunately, the new NK beam in Enclosure NEB will be further west than any of the previous beams passing through the enclosure and is further west than the position of the west wall of 109 at several locations but will be contained within NEB. Magnets for the NK beam must be located where there are presently columns which support the utilities. The NK magnets are close to the floor while the utilities are in general higher up. We were forced to cut away many of the columns on the downstream west side of 109 to position magnets in its place. We still must retain the upper part of the columns to support the utilities. The problem therefore was to transfer the weight of the utilities when the bottom part of the columns to which they previously attached no longer exits. The solution chosen was to attach rods from the top of the cut columns to the roof of Enclosure NEB which surrounds it. The roof of Enclosure NEB is made of concrete shielding blocks. The weight of the utilities and the remnants of Enclosure 109 no longer supported by the cut columns was transferred to the concrete blocks of the roof and then to the concrete walls making up Enclosure NEB. Since the pumps forcing water through the LCW pipes cause them to vibrate additional bracing was attached to the cut columns to prevent resonant vibrations. Once the column modifications are completed, one of the tasks which must be done is to check to see if any resonant vibrations are still induced. Any potential resonances will be noted and removed by additional bracing or changes in the stubs of the columns.

Downstream of Enclosure NEB will see even greater changes. An entirely new beam line will be installed from NEB to Lab F. To accomplish this some of the berm downstream of NEB will have to be removed. Although the NK beam as it exits NEB is still at a point where the berm is relatively low, by the time the beam reaches the end of the berm it must travel through what is now the part of the berm that has the greatest height. In addition, although Enclosure NEB contains the final bends in the beam line, we must build a new Enclosure NKC, to house quads and beam monitors between NEB and Lab F.

After the beam pipe is installed between Enclosures NEB and NKC, it will be necessary to return some of the dirt (approximately 1 meter or more) over the pipe. The section just downstream of Enclosure NEB will have still additional dirt piled upon it for about 50 feet. The purpose of this additional dirt downstream of Enclosure NEB is to act as a halo and neutron shield. The advice of Jorge Morfin and Anthony Malensek, the designers and builders of the NM Muon Beam, is that HALO does not do a good job in modelling low momenta halo particles and does not consider neutrons generated at all. Since dirt will be available from the removal of the berm to build the NK beam, some of it will be used to add to the berm just downstream of Enclosure NEB. For purposes of design, the 50 feet of berm was assumed to have a radius of 8 feet with a pipe penetrating it with 5.8 inches radius (HALO file BCHALO1 of 1025, 8 June 1988). Since the thick part of berm downstream of Enclosure NEB comes immediately after this enclosure several benefits are gained. First, the question of pipe alignment will be the least critical since the upstream end will be firmly anchored to the concrete wall at the downstream end of Enclosure NEB where it can be seen. The limiting apertures will be the magnet apertures in Enclosure NEB and unless the pipe downstream meanders wildly it should not become a limiting aperture while it is under the proposed thick part of the berm. Additionally, the thick part of the NK berm also serves to shield against accident conditions. The final bend of 28.166 mr in the NK beam is made by NKBW2 dipoles. If NKBW2 is off, there is no way that any beam can leave the pipe downstream of Enclosure NEB with the thick shielding around it. With NKBW2 off, any beam that penetrated over 270 feet to the next enclosure would be shifted to the east by over 7 feet from the NK beam line by the time it reaches Enclosure NKC. This would mean that most of the distance between Enclosures NEB and NKC would be through the dirt shield. The pipe downstream of Enclosure NEB is 12" diameter increasing to 16" in diameter for the last 80 feet or so of the pipe upstream of Enclosure NKC. The large diameter pipe at the downstream end allow some margin of error for pipe misalignment in a region where the beam size is growing. Thus, even if the Be filter upstream was not in place, there will be no way that hadrons could be transmitted much past the thick part of the NK berm if NKBW2 is off. Finally, the requirement for additional earth shielding just downstream of Enclosure NEB had the additional benefit in terms of contouring the berm for water removal. One of the problems with the area is the potential for rain water to become trapped in low area, for example between the neutrino berm and the NE beam berm. By requiring additional dirt to cover the NK beam just downstream of Enclosure NEB some of the problems with drainage of rain water is reduced.

Since a 12 inch diameter pipe is being considered for most the region between Enclosures NEB and NKC, not much tolerance is provided for the pipe to snake from Enclosure NEB to NKC. Care will be required to make sure that pipe is installed at the correct place and remains in the correct location after being covered by the berm. This will be a difficult task. However, it is important to use a small diameter pipe downstream of Enclosure NEB to help filter out the halo particles so the 12 inch diameter must be used for most of the way.

The quads in the new Enclosure NEC are required to satisfy Experiment 782's request for a beam which is tall, 40 to 50 cm full width, and narrow, and narrow as possible. Since the halo within the 100 cm wide by 50 cm high volume of the bubble chamber must be as free of halo as possible, it was necessary to employ large aperture quads. The quads that were chosen are the 8Q32's (these are quads from Argonne National Laboratory which is also known by the designation "8 NQ 32B") with an average effective length of 35.64 inches and a physical length of 41 inches. Since these quads will go in an enclosure that is closer to Lab F than Enclosure NEB, power and cooling water will be sent from Lab F rather than from Enclosure NEB. The choice of Lab F as the power source has the additional advantage of being accessible even when there is beam passing through Enclosure NEB. In the past we have had access problems with power supplies in Enclosure NEB. Enclosure NEB has the NE, NT and NK beams passing through it. While the 1989 running period will not see NT and NK operating during the same accelerator cycle, NE will be used by Experiment 690. There is a high probability that NE will be taking beam during the same accelerator cycle as the NK. By placing the power source at Lab F, a problem with the power supply for the quads at Enclosure NKC will not result in a need to make access into Enclosure NEB thereby shutting down NE.

Four 8Q32 quads were chosen for Enclosure NKC. With four of these quads, it will be necessary to run them at 1.58 KG/in at 196.28 GeV requiring at that gradient approximately 1200 Amps resulting in a voltage drop at each quad of approximately 38 Volts. These quads are able to run at a higher gradient. By keeping the current at approximately 1200 Amps, it will be possible to use flexible cables rather than hard bus to furnish power. With flexible cables the cost and difficulty of installation should be less than if hard bus was required. If hard bus was cheaper, it will be possible to reduce the number of quads needed down to two 8Q32's if desired. The final choice of the number of 8Q32's to use is a compromise between power requirements, how to deliver the power, the size of the enclosure to house the quads, and the availability of 8Q32's for use in NK beam and as spares. At the moment there seems to be a total of eight of the "8Q32B" quads at Fermilab. All but one was used on the Dichromatic Neutrino Train. I am told that there are two types of these quads. The two types differ in the resistance of the coils. I am told there are at least five of these with low resistance, i.e., lower power quads. Then there will be at least one spare quad assuming that the four quad design is satisfactory. The Electrical Group will be checking all of the 8Q32's to determine if any of them have problems and which of them have the low resistance coils. We will use the results of the checks to determine which of the quads to use in the NK beam.

In the final design of the new quad Enclosure NKC, it turned out that the length of the enclosure was governed not so much by the amount of space required by the quads but by another factor. The position of the final quads was governed by optical considerations. This position was in a region where the Neutrino Berm was still in place. A simple trench cut into the berm to install the new enclosure generated the problem of erosion. The erosion problem arose from the fact that the length of the quad enclosure was not long enough to reach the end of the berm. To solve the problem, the length of the precast concrete sections used to make Enclosure NKC was made longer than needed by the quads. The downstream portion of the concrete sections functioned as a retaining wall rather than as a part of the enclosure and was not entirely buried in the berm. In this way the walls of the berm could be kept from collapse even in bad weather.

Another factor which must be taken into consideration with the quads in Enclosure NKC will be the problem of final steering of the beam. The last horizontal bend and vertical trim are located at the downstream end of Enclosure NEB. Since the 8Q32 quads have a bore of 8.244 inches, we do not have trim magnets with matching or larger apertures to make any final corrections to the beam position at the bubble chamber. Thus, if we need any final position corrections at the bubble chamber, we must do it by using the quads in Enclosure NKC. This will mean that we must be able to move the position of the quads enough to have the quad steer as well as focus the beam. The design for the stands of the quads must take this into consideration to make the task of aligning the quads relatively easy keeping in mind that cost is to be kept low as well. The Mechanical Group that will design the stands has been made aware of this requirement.

It is important to note that in the proposed design, the HALO Monti Carlo predictions indicate that a halo/muon ratio that is acceptable to Experiment 782 can be achieved without the use of toroids or spoilers. Hence there are no toroids or spoilers planned for incorporation into the NK beam line at this time. It would have been nice to have some toroids and spoilers in hand if measurements revealed a need for them. However, any toroids or spoilers would have added to the cost of building this beam line. The mandate calls for a beam line that is inexpensive as possible.

The NK beam line downstream of Enclosure NKC will be operated with air at 1 atmosphere. The distance from the downstream end of the quads in Enclosure NKC to the Tohoku Bubble Chamber is about 150 feet. With this much air at 1 atmosphere, we will have approximately 0.06 interaction lengths between NKC and the bubble chamber. If the span between NKC and the bubble chamber was made into a helium bag at 1 atmosphere, there would be approximately 0.013 interaction lengths. It is believed that any multiple scattering caused by the air downstream of Enclosure NKC will be acceptable to the experiment. If it proves that there is unacceptable amount of multiple scattering caused by the air, then a helium bag will be installed downstream of NKC.

Special Instrumentation Needs

The installation of Beam Position Monitors, BPM's, in Enclosures G-2 and NW1 is being considered by Sam Childress for the NE/NT/NK beams. These BPM's will required two different readout electronics associated with each BPM. The different readout electronics will enable the monitoring of both the slow spill and the mini-pings.

Investigation was made as well on SWIC's to see if it is possible to attach two different readout electronics to them as well. During the

1987-1988 run, it was not possible to monitor the slow and fast spill on the same accelerator cycle since the readout electronic could not be set up to read both of them during the same cycle. Since the users are going to be different for the slow spill and the mini-pings sent down the NE beam, it would be helpful to have the capability of monitoring both types of spill on the same cycle. The results indicate that we will need independent SWIC's for the slow and mini-ping components of the extracted beam.

We will need to be able to momentum tag the muons entering the bubble chamber and to monitor the halo. For this we will need scintillators and wire chambers at various positions along the beam line. As noted above in the discussion of Enclosure NEB, a special effort was made to provide a gap of approximately 29.5 feet between the last quad in the enclosure and the start of the final bend string in the NK beam for this purpose. The exact nature of the instrumentation to be installed will be left to the members of the Experiment 782 collaboration.

Design Approach Taken for the NK

The spot size of the beam at the target in Enclosure NE8 was based upon the spot size observed during the running period which ended in 1988. The optics assumes that the quadrupoles in Enclosure NE8 are used to focus the primary proton beam onto the NT/NK target. This condition is important to keep in mind since the quads in Enclosure NE8 can be moved out of the NT/NK beam into the NE beam. However, at this time there are no plans that I know of which will require the use of these quads in the NE beam during the next running period.

The optical condition specified to TRANSPORT for the initial post target portion of the beam line required the following. A point to point imaging condition of the hadron beam focused at the upstream end of NKAQ, the field lens. To accomplish this the existing quadrupoles in the NT/NK beam in Enclosures NE9 were permitted to vary their field gradients but not their positions.

The next optical step required that the beam negotiate the apertures of Enclosure NEB as cleanly as possible. This enclosure aside from the Be filter consists starting at the upstream end and going downstream: three

5-1.5-240 dipoles in series, a pair of 3Q120 which are independently controllable, a pair of 5-1.5-240 dipoles in series and a 4-4-30 vertical trim. Since the Be hadron filter is assumed to be located just upstream of the upstream most 5-1.5-240 dipole there will be multiple scattering introduced by the filter. However, since TRANSPORT cannot handle multiple scattering, the optical condition used for beam transport through Enclosure NEB assumed that the filter was not present and required a point to point imaging with the image to be formed approximately 15' downstream of the end of the enclosure. After the quad tune for Enclosure NEB was determined for this condition, the next step taken was to incorporate these values into HALO.

We know based upon muon yield studies conducted in the NH beam line prior to the end of the 1988 fixed target run that the muon yield is maximum in the region from about 150 to 200 GeV. Experiment 782 is interested in observing muon interactions in this approximate energy range. Thus, for the initial TRANSPORT/HALO studies, the hadron beam momenta upstream of the Be filter was set at 200 GeV/c. Running HALO at this point with 21.502' of Be filter in the first 5-1.5-240 in NEB, several parameters were determined. The mean momentum of the muons downstream of Enclosure NEB was approximately 196.22 GeV/c. The phase space of the beam downstream of Enclosure NEB was determined.
The values obtained for the phase space parameters where then used in a TRANSPORT file which began downstream of Enclosure NEB to determine the position and field gradients for the quadrupoles which formed the beam into the desired vertical stripe at the bubble chamber. The final transport transport results were then incorporated back into the complete HALO file which began at the target in Enclosure NE8 and went to Lab F. This then was the version of the NK beam which seemed to meet the requirements of Experiment 782.

It is important to note that it was necessary to employ large aperture quads in the new Enclosure NKC. Many attempts were made to try to design a beam line using quads smaller in apertures than the 8Q32's. When smaller aperture quads were employed, the results were always unacceptably high ratios of halo/muon. Repeated attempts were also made to try to move the quads downstream of Enclosure NEB closer to NEB but these attempts also were unsatisfactory. When quads were moved closer to Enclosure NEB the aspect ratio of the vertical stripe became uncontrollable due to the distances involved between the quads and the bubble chamber.

Once the design work was completed for 200 GeV/c hadrons a HALO study was made of the muon yields for different momenta hadrons incident on the Be filter. The figures below show the predicted results for the muon yield and for the associated muon/halo ratio at the bubble chamber.

It should be also noted that there is an identifiable major source of halo which reaches all of the way to the bubble chamber. This source not surprisingly is the Be filter at the upstream end of Enclosure NEB. When a scatter plot is made of the halo at the entrance to Enclosure NEB the halo which exists is confined mostly to a cross sectional area which is equivalent to an aperture of NKBW1. By the time the beam passes through the Be hadron filter, the NKBW1 bend string and reaches NKBQ1, the first 3Q120 in Enclosure NEB, there is a pronounced presence of halo on the west ,i.e., low momenta, side going out to the west from the center of the beam line to about 5 inches and beyond. The muons leaving NKBW1-3, 5-1.5-240, aperture is also in the form of a spray. The entire aperture of the magnet is not filled. When a scatter plot is made of the beam exiting NKBW1-3 there is an empty region on the east side of the magnet (see figure 3). On the west side the muons occupy the aperture right up to the edge. By the time a scatter plot is made at the downstream end of NKBQ1 the halo has split into tow distinct components. There is one component which travels down the beam pipe along with the muons. Additionally, there is a halo component which is approximately the same in intensity as the one in the quad aperture which is at least 2.5 inches from the center of the beam line. When the two groups of halos reach the downstream end of NKBQ2 the separation is even more pronounced. The half which did not go through the quad aperture now is at least 7.5 inches west of the beam line and is centered at about 8.5 inches west of the beam line and is aimed directly at the Tohoku Bubble Chamber.

The work described here contains the invaluable advice and help of many people. Among them are Anthony Malensek, Jorge Morfin, Linda Stutte, Norm Bosek, Leon Beverly, Aga Visser and others. Without their patience and aid this work would have been impossible to carry out.

NK BEAM TO LAB F B.C., TGT AT NE8 88/07/21.

500 GEV

POSITION Z CENT.	X CENT.	Y CENT.	CODE	ELEMENT CODE	POWER SUPPLY	B/G(KG) OR (KG/IN)
6279.00	-30.05	745.46	NKTGT	NT/NK TARGET, 15" ALUMINUM BLOCK	NK8TG	
6285.50	-30.25	745.45	NK8UE	DIPOLE 5-1.5-120 FRD10998 -64.42DG	NK8UE	16.140
6312.76	-31.10	745.43	NKDP	U.S. END, 10' BEAM DUMP, Z=6312.75	NK8DP	
6322.75	-31.42	745.43	NKDP	D.S. END, 10' BEAM DUMP	NK8DP	
6426.70	-34.69	745.39	NKBUBD	U.S. END, BACKUP BEAM DUMP IN PIPE		
6436.70	-35.00	745.38	NKBUBD	D.S. END, BACKUP BEAM DUMP IN PIPE		
6477.00	-36.27	745.37	NK9Q1-1	QUAD 3Q120 FRD11810	NK9Q1	3.331
6488.99	-36.65	745.37	NK9Q1-2	QUAD 3Q120 FRD11811	NK9Q1	3.331
6503.48	-37.11	745.36	NK9CH	COLLIMATOR, HORIZONTAL, 10'	NK9CH	
6526.75	-37.84	745.35	NK9Q2-1	QUAD 3Q120 FRD11812	NK9Q2	-2.975
6538.24	-38.20	745.35	NK9Q2-2	QUAD 3Q120 FRD11269	NK9Q2	-2.975
6557.40	-38.78	745.34	NK9W-1	DIPOLE 5-1.5-240 FRD10500	NK9W	-16.903
6570.64	-39.14	745.33	NK9VR	TRIM 4-4-30 FRD10922 -64.48DG	NK9VR	2.462
6587.50	-39.54	745.33	NK9W-2	DIPOLE 5-1.5-240 FRD10501	NK9W	-16.903
6609.00	-39.95	745.32	NK9W-3	DIPOLE 5-1.5-240 FRD10503	NK9W	-16.903
6630.49	-40.23	745.32	NK9W-4	DIPOLE 5-1.5-240 FRD10904	NK9W	-16.903
6646.99	-40.36	745.31	NK9W-5	DIPOLE 4-2-120 FRD11640	NK9W	-16.903
6654.74	-40.40	745.31	NK9V	TRIM 4-4-30 FRD10922 90.000DG	NK9VR	0.000
6670.00	-40.45	745.31	NK9CV	COLLIMATOR, VERTICAL, 10'	NK9CV	
6693.50	-40.54	745.30	NKSCIN	4 X 4" VERT. & HORI. SCINTILLATORS	NK9SC	
6695.50	-40.55	745.30	NKWALL	D.S. END OF ENCL. NE9 IS AT Z=6695.5		
6953.56	-41.51	745.23	NKWALL	U.S. END OF ENCL NEA IS AT Z=6953.5		
6956.58	-41.52	745.23	NKACH			
6960.58	-41.53	745.23	NKSCIN	4 X 4" SCINTILLATOR, VERTICAL	NKASC	
6974.50	-41.58	745.22	NKAQ	QUAD 3Q120 FRD10313	NKAQ	4.371
6981.00	-41.61	745.22	NKWALL	D.S. END OF ENCL. NEB IS AT Z=6980.996		
7063.00	-41.91	745.20	NKWALL	U.S. WALL, ENCL. NEB, Z=7063.		
7066.00	-41.92	745.20	NKSCIN	4 X 4" SCINT., VERT. & HORIZ.	NKBSC	
7067.00	-41.93	745.20	NKSWIC	SWIC, VERT. & HORIZONKAL, 2MM	NKBWC	
7069.49	-41.94	745.20	NKBBEU	U.S. END, 21.5' BE HADRON FILTER		
7090.99	-42.02	745.19	NKBBED	D.S. END, 21.5' BE HADRON FILTER		
7102.49	-42.00	745.19	NKBW1-1	DIPOLE 5-1.5-240 FRD10512	NKBW1	-45.000
7123.99	-41.72	745.18	NKBW1-2	DIPOLE 5-1.5-240 FRD10513	NKBW1	-45.000
7145.49	-41.10	745.17	NKBW1-3	DIPOLE 5-1.5-240 FRD10515	NKBW1	-45.000
7171.97	-39.95	745.17	NKBQ1	QUAD 3Q120 FRD11268	NKBQ1	-9.351
7209.95	-38.21	745.16	NKBQ2	QUAD 3Q120 FRD10317	NKBQ2	10.773
7257.50	-35.99	745.14	NKBW2-1	DIPOLE 5-1.5-240 FRD10519	NKBW2	-38.533
7278.44	-34.74	745.14	NKBW2-2	DIPOLE 5-1.5-240 FRD10517	NKBW2	-38.533
7291.66	-33.81	745.13	NKBV	TRIM 4-4-30 FRD10523 90.000DG	NKBV	0.000
7298.80	-33.29	745.13	NKWALL	D.S. WALL, ENCL. NEB, Z=7298		
7561.35	-13.88	745.06	NKWALL	U.S. WALL, ENCL. NKC		
7567.90	-13.39	745.06	NKCQ-1	QUAD 8Q32 FRD?????	NKCQ	4.025
7572.86	-13.02	745.06	NKCQ-2	QUAD 8Q32 FRD?????	NKCQ	4.025
7577.82	-12.66	745.05	NKCQ-3	QUAD 8Q32 FRD?????	NKCQ	4.025
7582.77	-12.29	745.05	NKCQ-4	QUAD 8Q32 FRD?????	NKCQ	4.025
7591.32	-11.66	745.05	NKWALL	D.S. WALL, ENCL. NKC		

7704.00	-3.33	745.02	NKWALL	U.S. WALL, ENCL. NCE, LAB F, Z=7704
7740.00	-.67	745.01	NKBC	TOHOKU BUBBLE CHAMBER, Z=7740

On file as JT18N1B of 1204, 21 July 1988

This is BSHEET version of NK Beam TRANSPORT file: JT18N1 of 1435, 8 June 1988
Quad tunes downstream of Be filter based on HALO file: BCHALO4 of 1705, 6 July 1988
Upstream and downstream ends of Enclosure NKC are not certain yet

This BSHEET has been corrected for Earth's curvature.

Given below is a tentive cost estimate for this project made by the Construction and Engineering Services Group at Fermilab.

Cost Estimate

Cost estimate by Construction and Engineering Services Group
7 September 1988

I. Site Work:		
	A. Site Demolition	$1,600
	B. Site Preparation	$2,000
	C. Earthwork	$19,100
	D. Paving	$1,100
	E. Sewage and Drainage	$2,900
	F. Site Improvements & Low Conductivity Water Piping	$9,600
	G. Beam Pipe	$14,800
II. Concrete:		
	A. Cast in place	$9,400
	B. Precast	$35,100
III. Mechanical:		
		$3,200

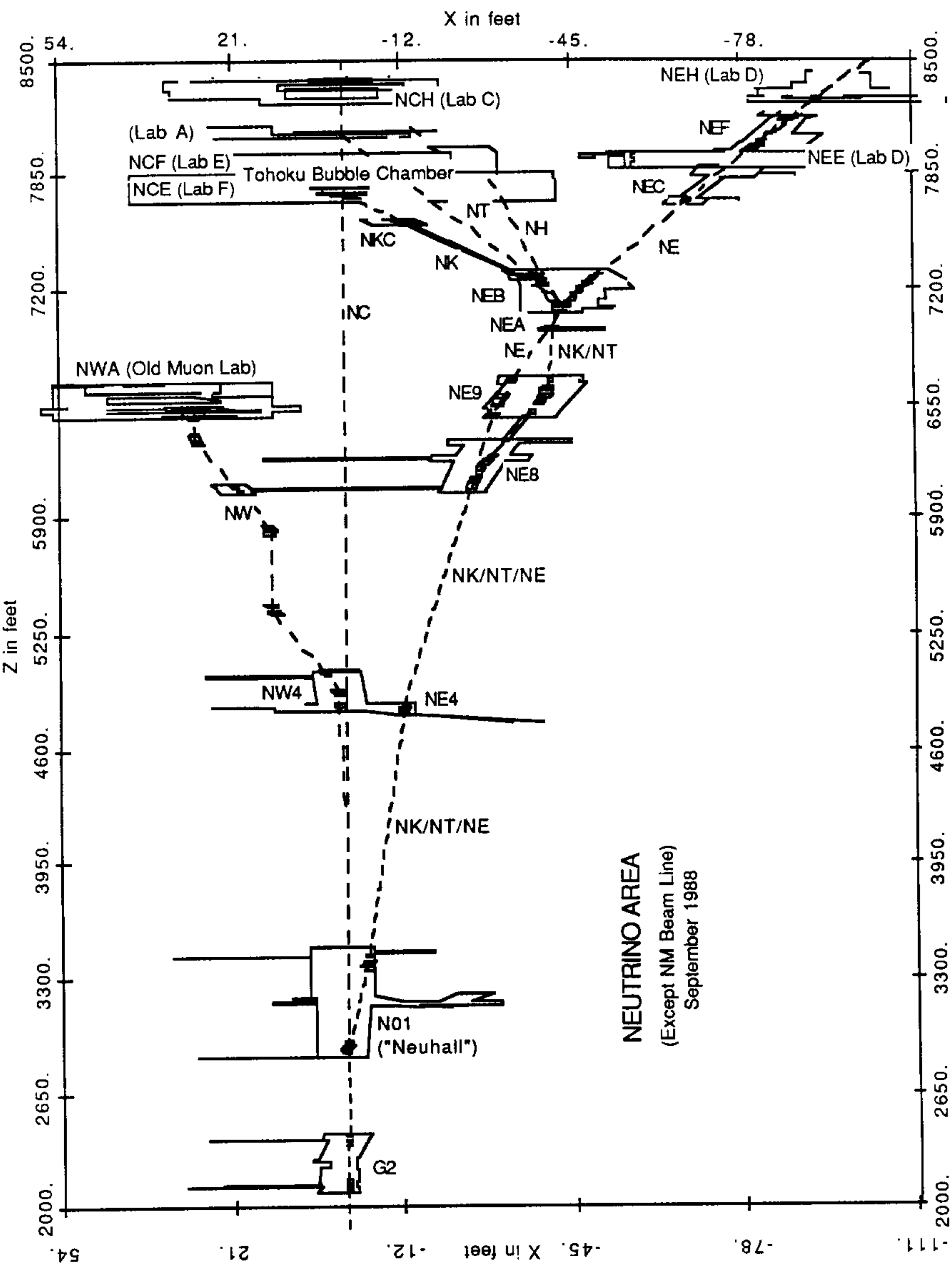
IV. Electrical:

A. Electrical Work	$6,100
B. Electrical Communication Duct	$4,600

Subtotal: $109,500

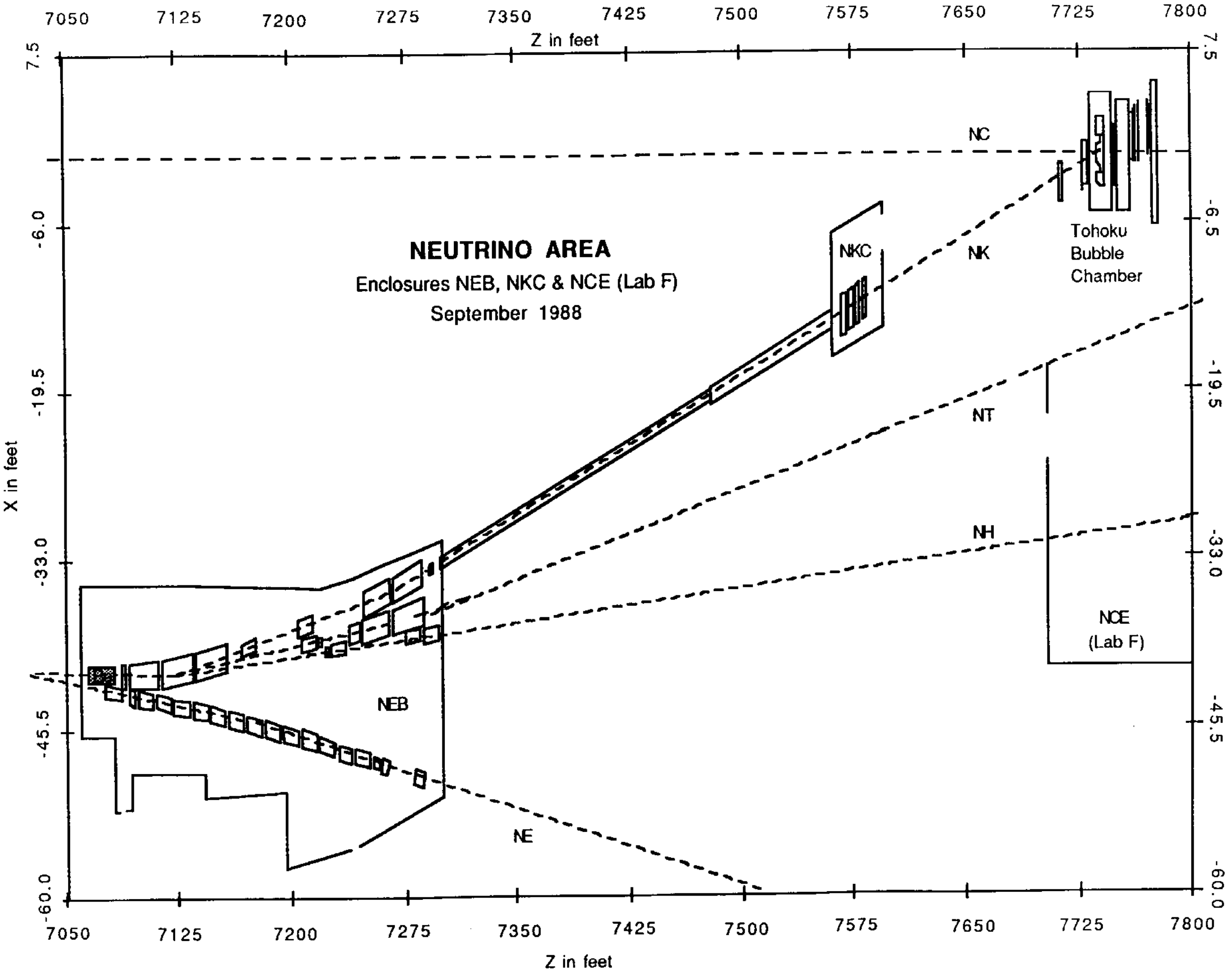
Overhead and Profit (20%): $21,500

Total: $131,400



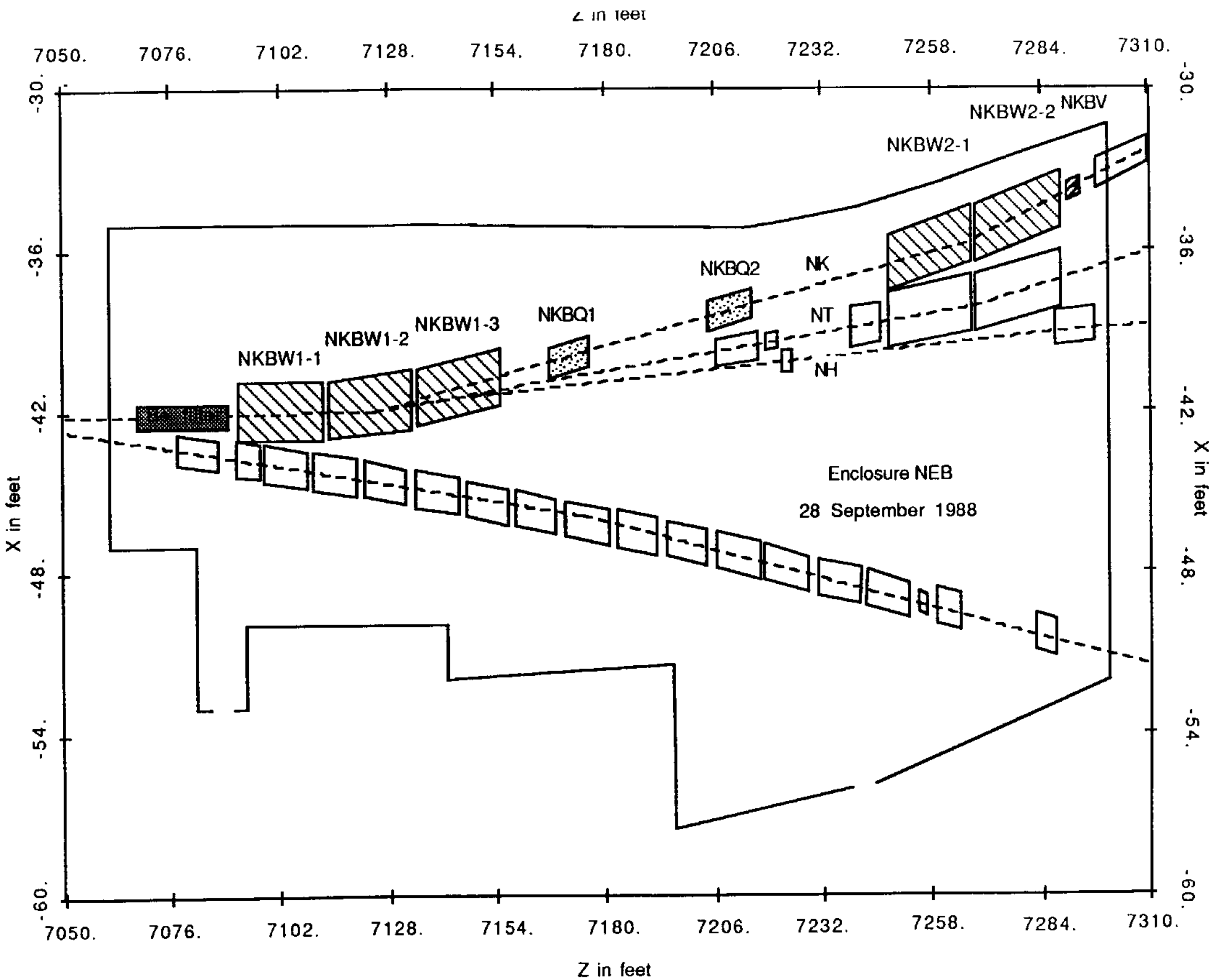
X in feet
54.
21.
-12.
-45.
-78.
-111.
Z in feet
8500.
7850.
7200.
6550.
5900.
5250.
4600.
3950.
3300.
2650.
2000.
NEH (Lab D)
NCH (Lab C)
(Lab A)
NEF
NCF (Lab E)
NEE (Lab D)
Tohoku Bubble Chamber
NCE (Lab F)
NEC
NT
NH
NKC
NE
NK
NEB
NC
NEA
NE
NK/NT
NWA (Old Muon Lab)
NE9
NE8
NW
NK/NT/NE
NW4
NE4
NK/NT/NE
NEUTRINO AREA
(Except NM Beam Line)
September 1988
N01
("Neuhall")
G2

figure 1



NEUTRINO AREA
Enclosures NEB, NKC & NCE (Lab F)
September 1988
Z in feet
X in feet
7050
7125
7200
7275
7350
7425
7500
7575
7650
7725
7800
7.5
-6.0
-19.5
-33.0
-45.5
-60.0
-6.5
NC
NK
NT
NH
NE
NKC
NEB
NCE
(Lab F)
Tohoku
Bubble
Chamber

figure 2


Z in feet
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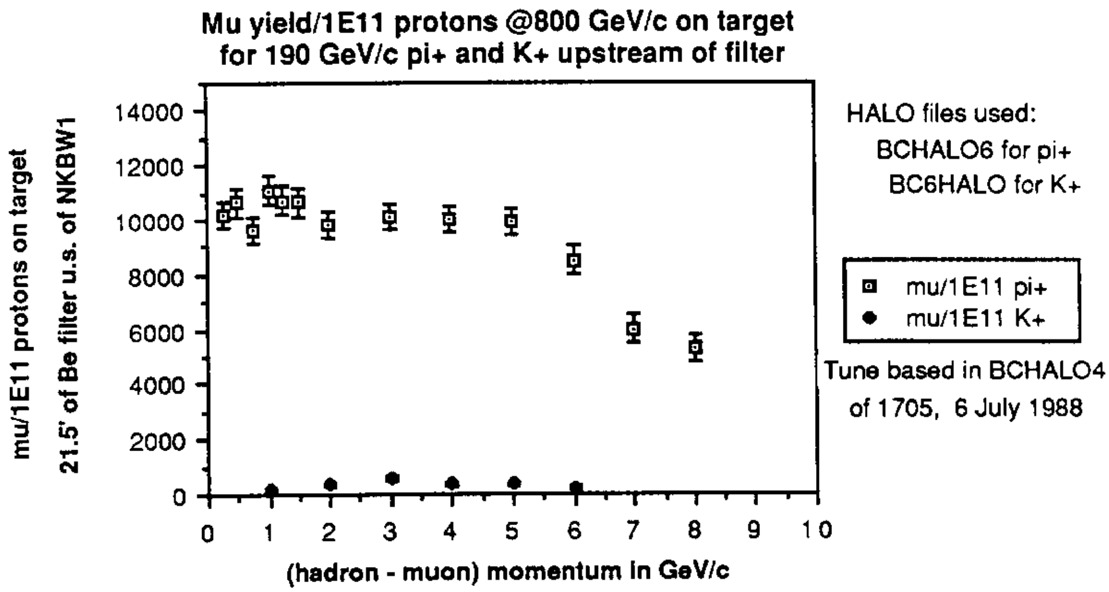
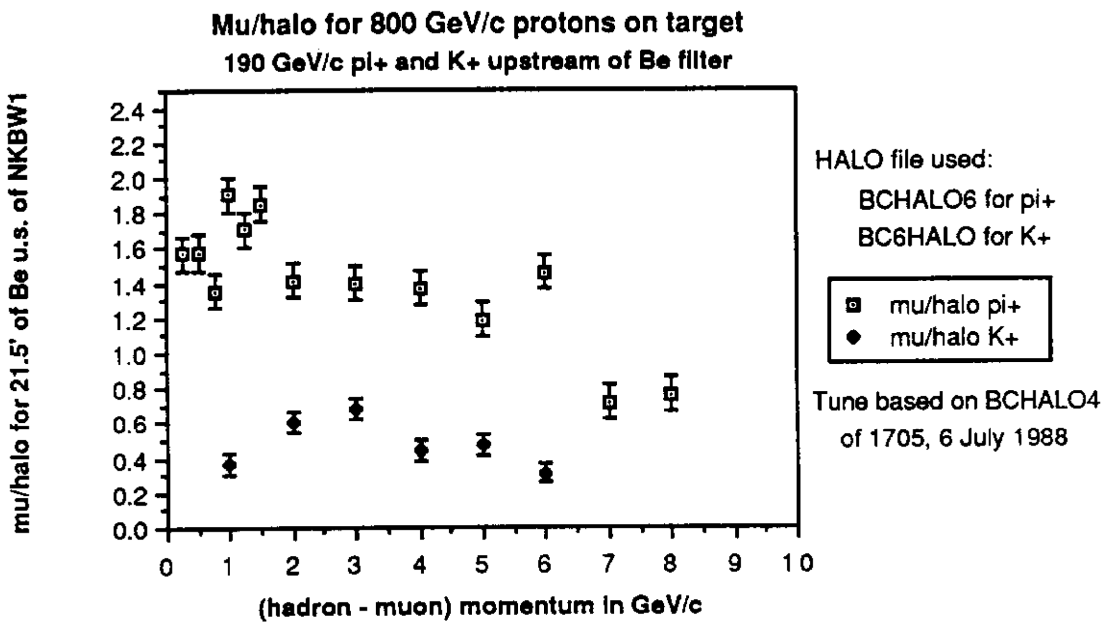
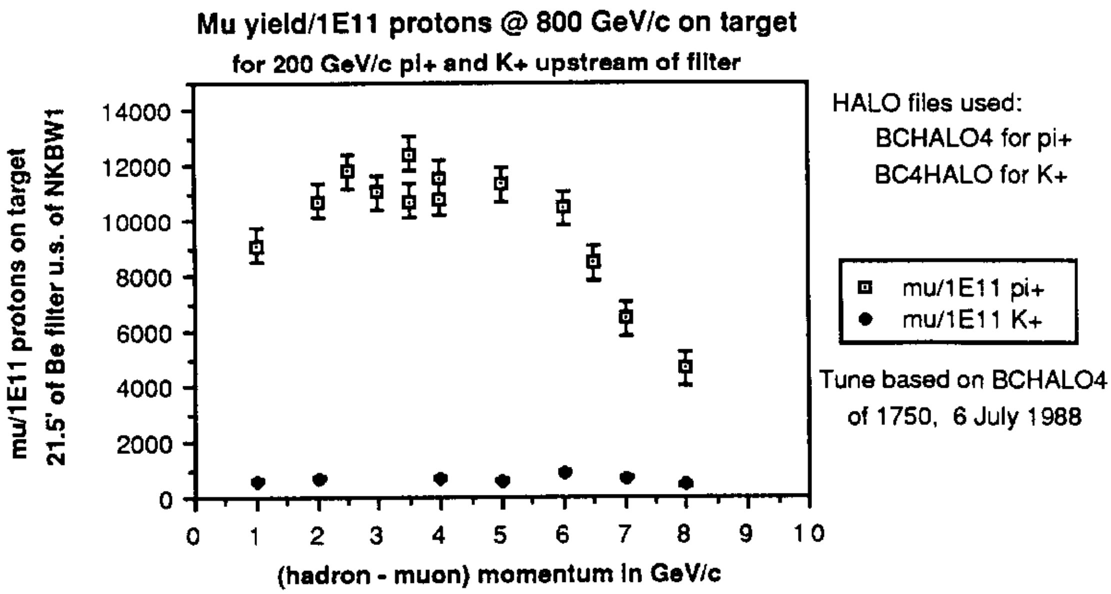
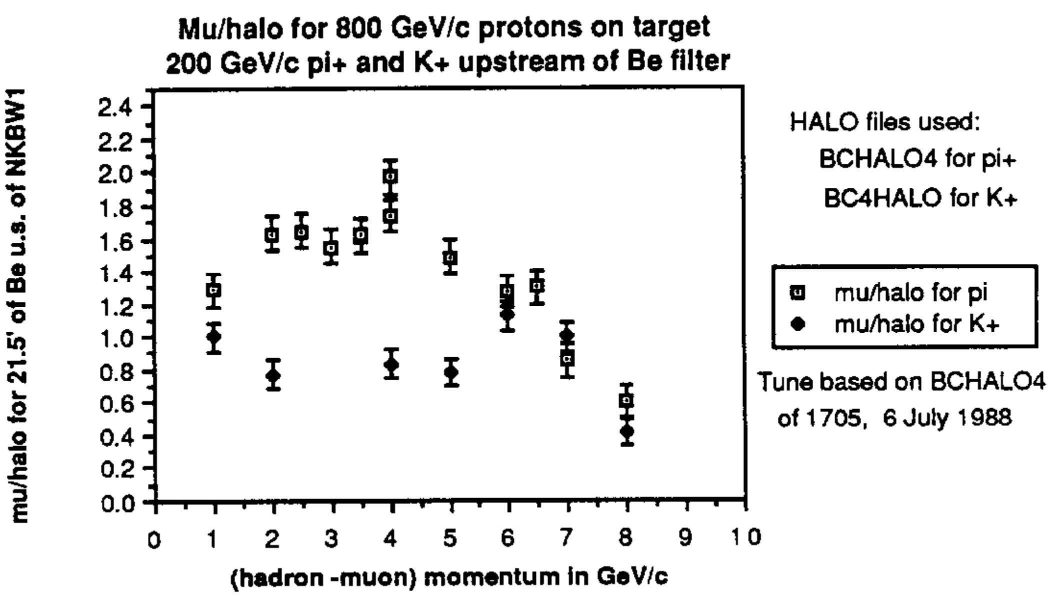
7076.
7102.
7128.
7154.
7180.
7206.
7232.
7258.
7284.
7310.
-30.
-36.
-42.
-48.
-54.
-60.
X in feet
NKBW2-2
NKBV
NKBW2-1
NKBQ2
NK
NT
NH
NKBQ1
NKBW1-1
NKBW1-2
NKBW1-3
Enclosure NEB
28 September 1988

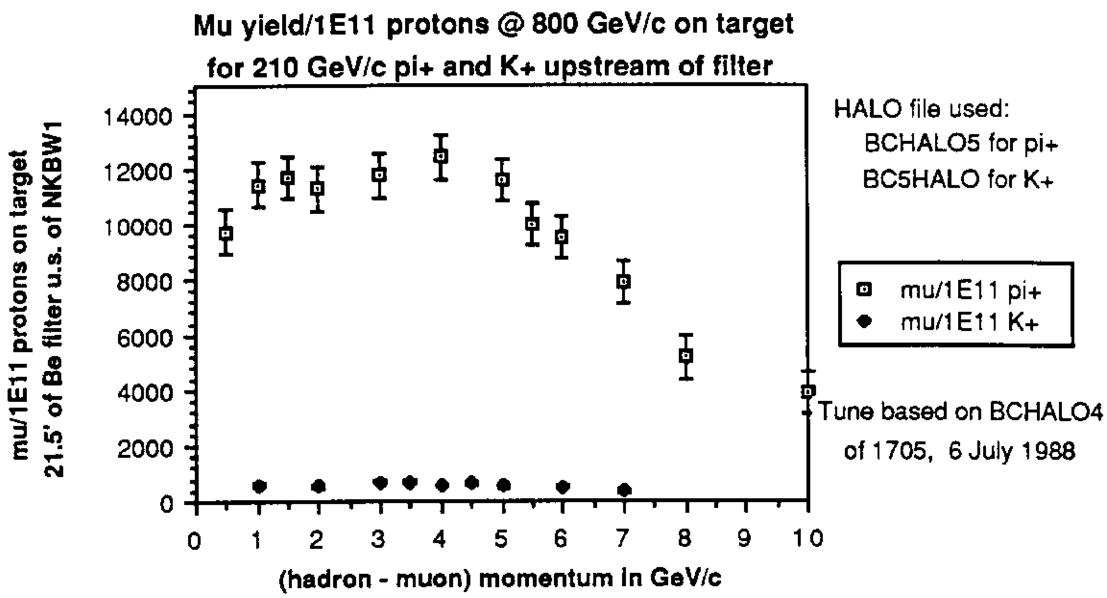
figure 3

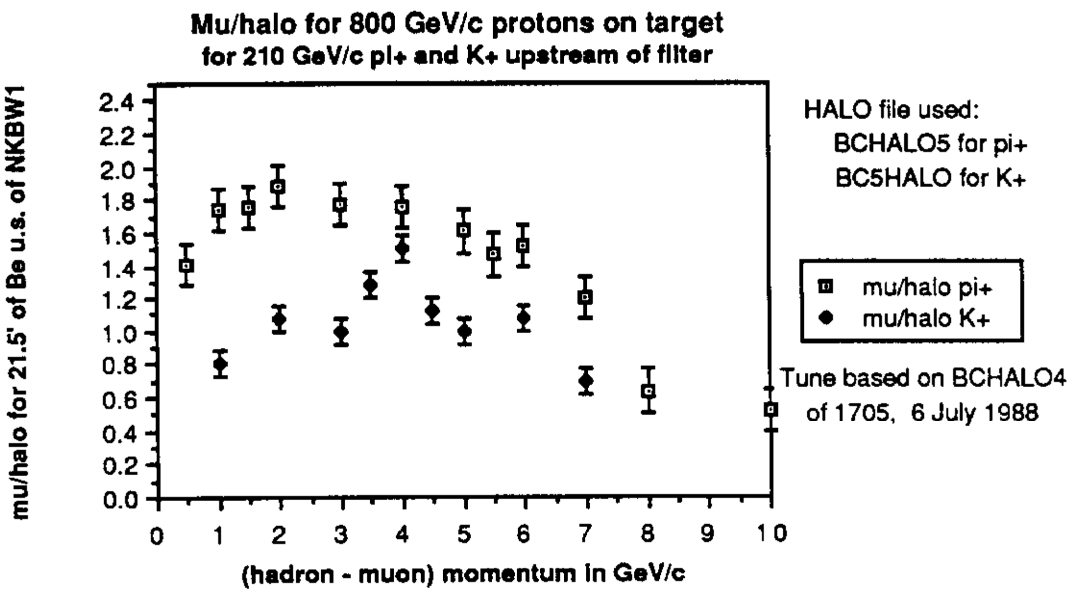

Mu yield/1E11 protons @800 GeV/c on target
for 190 GeV/c pi+ and K+ upstream of filter
mu/1E11 protons on target
21.5' of Be filter u.s. of NKBW1
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
5
6
7
8
9
10
(hadron - muon) momentum in GeV/c
HALO files used:
BCHALO6 for pi+
BC6HALO for K+
mu/1E11 pi+
mu/1E11 K+
Tune based in BCHALO4
of 1705, 6 July 1988

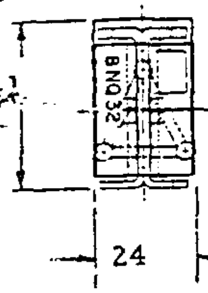

Mu/halo for 800 GeV/c protons on target
190 GeV/c pi+ and K+ upstream of Be filter
mu/halo for 21.5' of Be u.s. of NKBW1
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
10
(hadron - muon) momentum in GeV/c
HALO file used:
BCHALO6 for pi+
BC6HALO for K+
mu/halo pi+
mu/halo K+
Tune based on BCHALO4
of 1705, 6 July 1988


Mu yield/1E11 protons @ 800 GeV/c on target
for 200 GeV/c pi+ and K+ upstream of filter
mu/1E11 protons on target
21.5' of Be filter u.s. of NKBW1
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10
(hadron - muon) momentum in GeV/c
HALO files used:
BCHALO4 for pi+
BC4HALO for K+
mu/1E11 pi+
mu/1E11 K+
Tune based on BCHALO4
of 1750, 6 July 1988

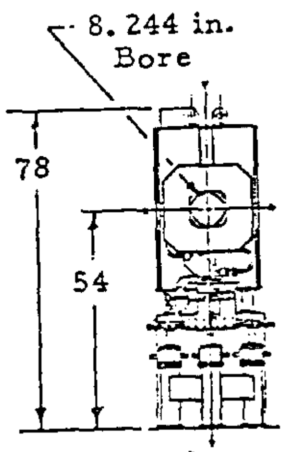

Mu/halo for 800 GeV/c protons on target
200 GeV/c pi+ and K+ upstream of Be filter
mu/halo for 21.5' of Be u.s. of NKBW1
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0 1 2 3 4 5 6 7 8 9 10
(hadron -muon) momentum in GeV/c
HALO files used:
BCHALO4 for pi+
BC4HALO for K+
mu/halo for pi
mu/halo for K+
Tune based on BCHALO4
of 1705, 6 July 1988


Mu yield/1E11 protons @ 800 GeV/c on target
for 210 GeV/c pi+ and K+ upstream of filter
mu/1E11 protons on target
21.5' of Be filter u.s. of NKBW1
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10
(hadron - muon) momentum in GeV/c
HALO file used:
BCHALO5 for pi+
BC5HALO for K+
mu/1E11 pi+
mu/1E11 K+
Tune based on BCHALO4
of 1705, 6 July 1988

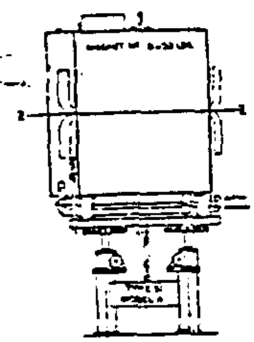

Mu/halo for 800 GeV/c protons on target
for 210 GeV/c pi+ and K+ upstream of filter
mu/halo for 21.5' of Be u.s. of NKBW1
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0 1 2 3 4 5 6 7 8 9 10
(hadron - muon) momentum in GeV/c
HALO file used:
BCHALO5 for pi+
BC5HALO for K+
mu/halo pi+
mu/halo K+
Tune based on BCHALO4
of 1705, 6 July 1988



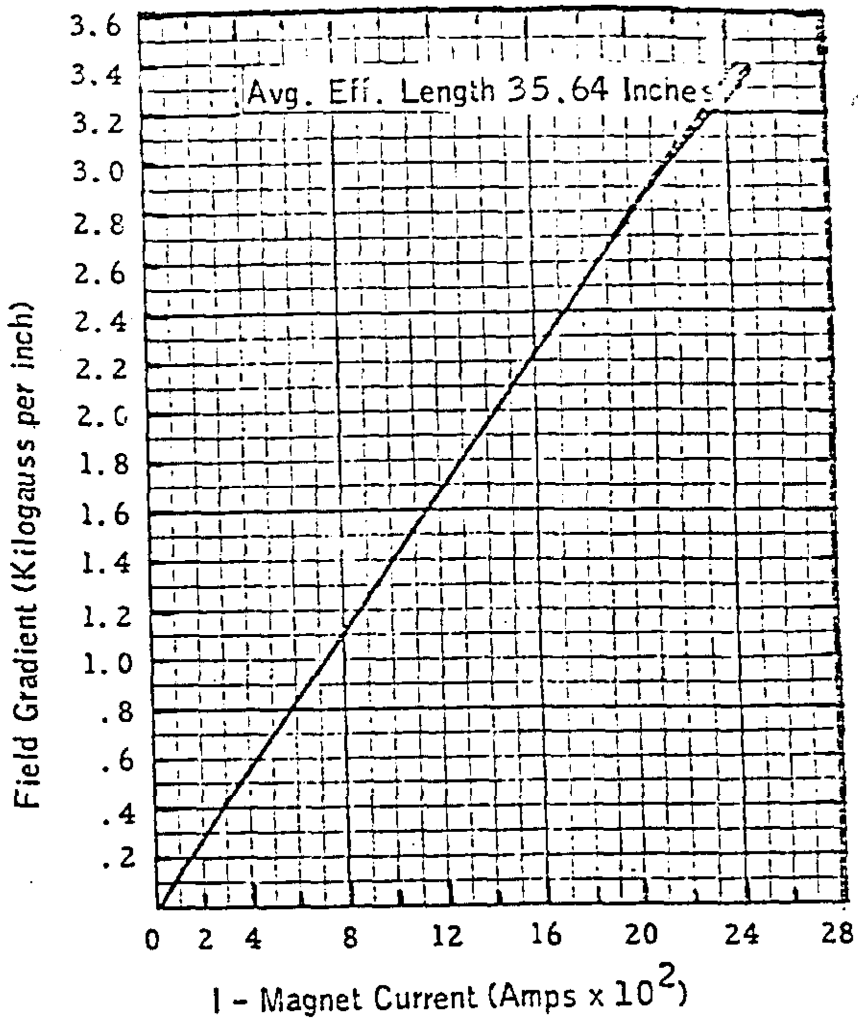
TOP VIEW



END VIEW



SIDE VIEW



Current (Amps)	Terminal Voltage (Volts)	Gauss/ Inch
300	9	421
400	-	560
600	19	839
800	25	1118
1000	32	1396
1200	38	1675
1400	44	1951
1600	50	2226
1800	56	2503
2000	63	2772
2200	70	3029
2400	77	3273
2500	81	3386
Errors	±2%	+0.1%

		Design Data 8 NQ 32B
Total Weight:	4.4 Tons	
Measured Data		
Voltage	81 Volts dc	73 Volts dc
Current	2500 Amps dc	2750 Amps dc
Power	203 kW	201 kW
Field Strength	14 kG	15 kG
Cooling Water (System Pressure Drop 200 psi)		
No. of Circuits	12	
Pressure Drop		
Flow	19 gpm	19.2 gpm
Temp. Rise	70° F	70° F

FERMILAB ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE
PSI	PING		

SUBJECT: NEUTRINO, GORDON'S PING

NAME: A.T. VISSER

DATE: 3/4/88 REVISION DATE:

COIL

COIL AVERAGE TURN LENGTH = $57\frac{1}{8}$"

TOTAL WIRE LENGTH = $600\frac{1}{2}$ FT

COIL WIRE AWG #10, 600V, 90°C, Cu

COIL $R_{25°C} = 0.678\ \Omega$

$R_{90°C} = 0.855\ \Omega$

COIL RATING = 20 ADC, 600 V

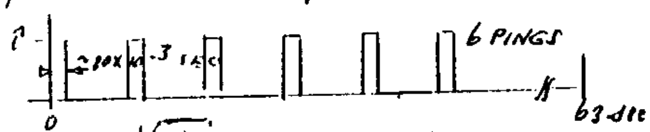
MAGNET

B = 6.18 KG 64.77 cm LONG 4 KGM

$B = \mu_0 H \rightarrow H = \frac{0.618}{4\pi 10^{-7}} = 491783\ AT/m$

$HT/_{2"} = 24{,}982$ $N = 140$ $\hat{I} = 178.5\,A$

OPERATE



$I_{RMS} = \hat{I}\sqrt{\frac{.12}{63}} = 7.8\,A$ (24.6 A AT 6x 200 ms PING WIDTH)

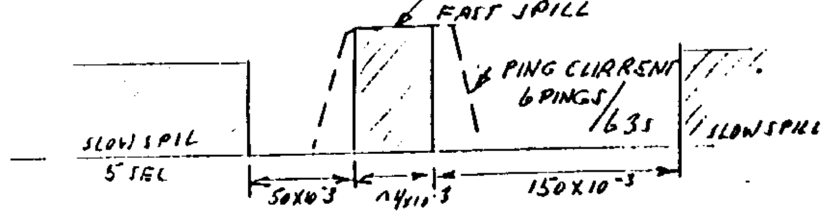
$L = \frac{N\Phi}{\hat{I}}$ $\frac{140 \times 0.618 \times 0.6477 \times 2.0625 \times 2.54 \times 10^{-2}}{178.5}$

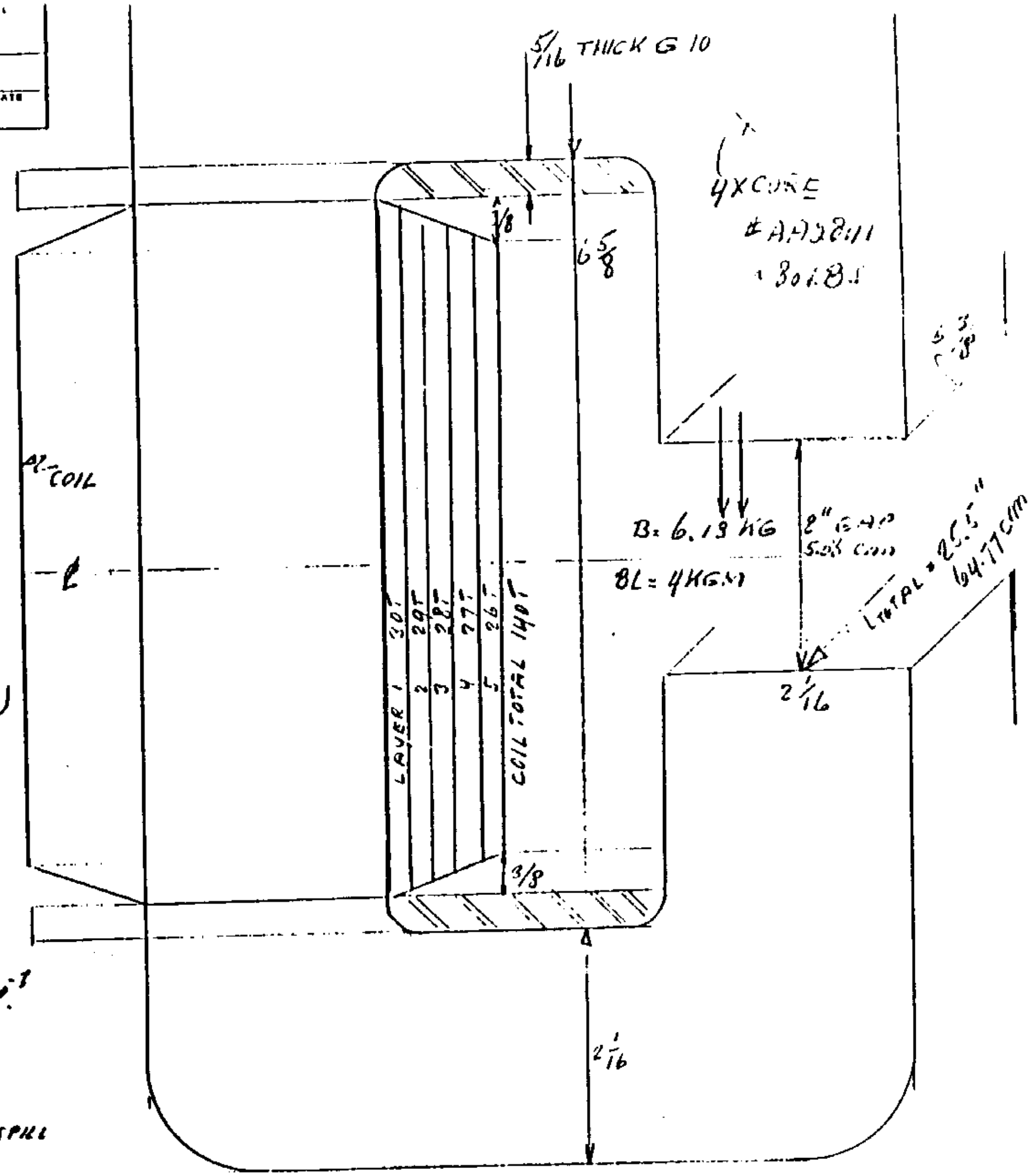
$L = 16.5 \times 10^{-3}$ HENRY

$\frac{1}{2} L \hat{I}^2 = 262$ JOULES

STEEL GOOD AT < 100 Hz

PING WINDOW TYPICAL





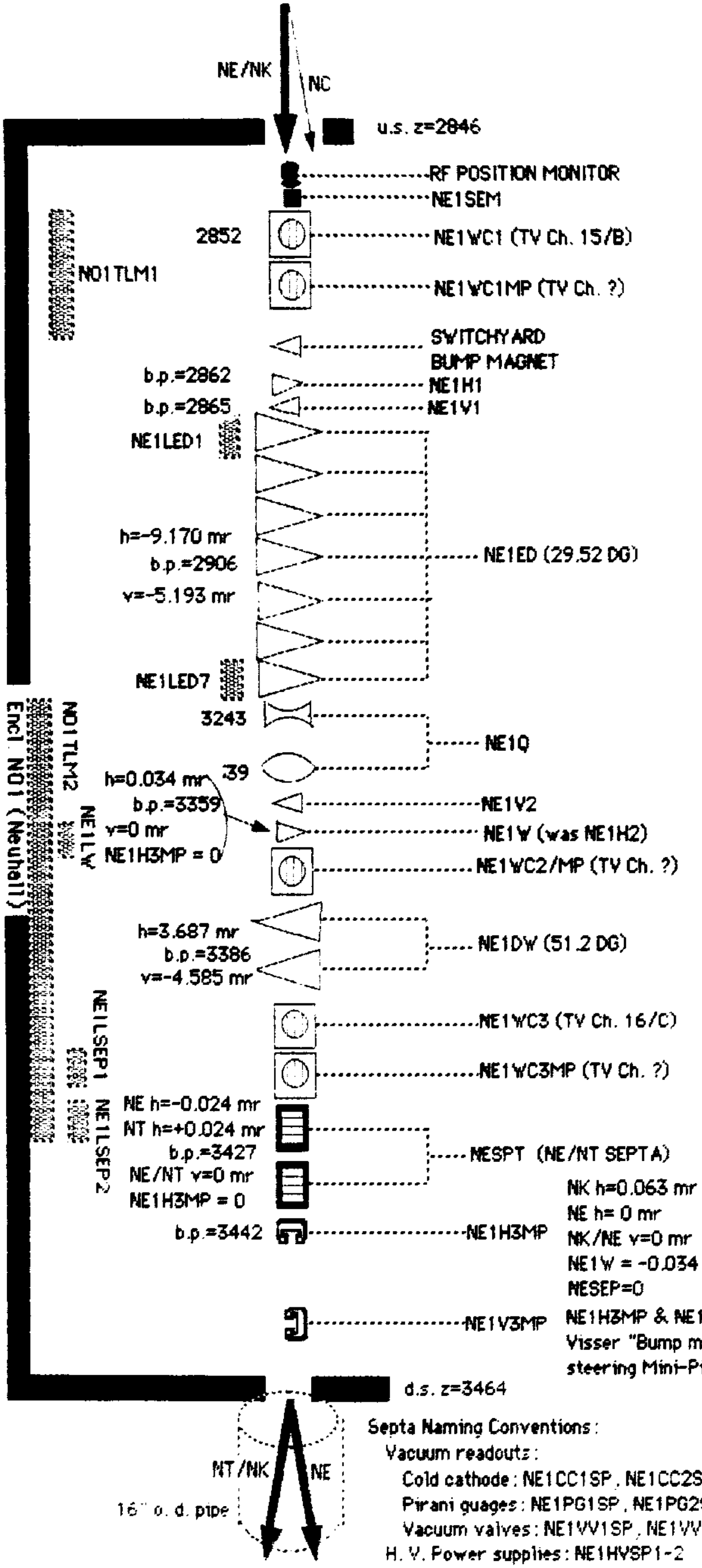
Fermilab

On file as "NE/NT/NK Layout 5a1"
Last update: 27 July 88
Gordon Koizumi

Transport files:
JT18N1 of 1435, 8 June 88
JT18M2 of 1505, 8 June 88
NTCAL3B of 1855, 25 Nov. 88
NEPI6S1 of 1843, 18 Dec. 88

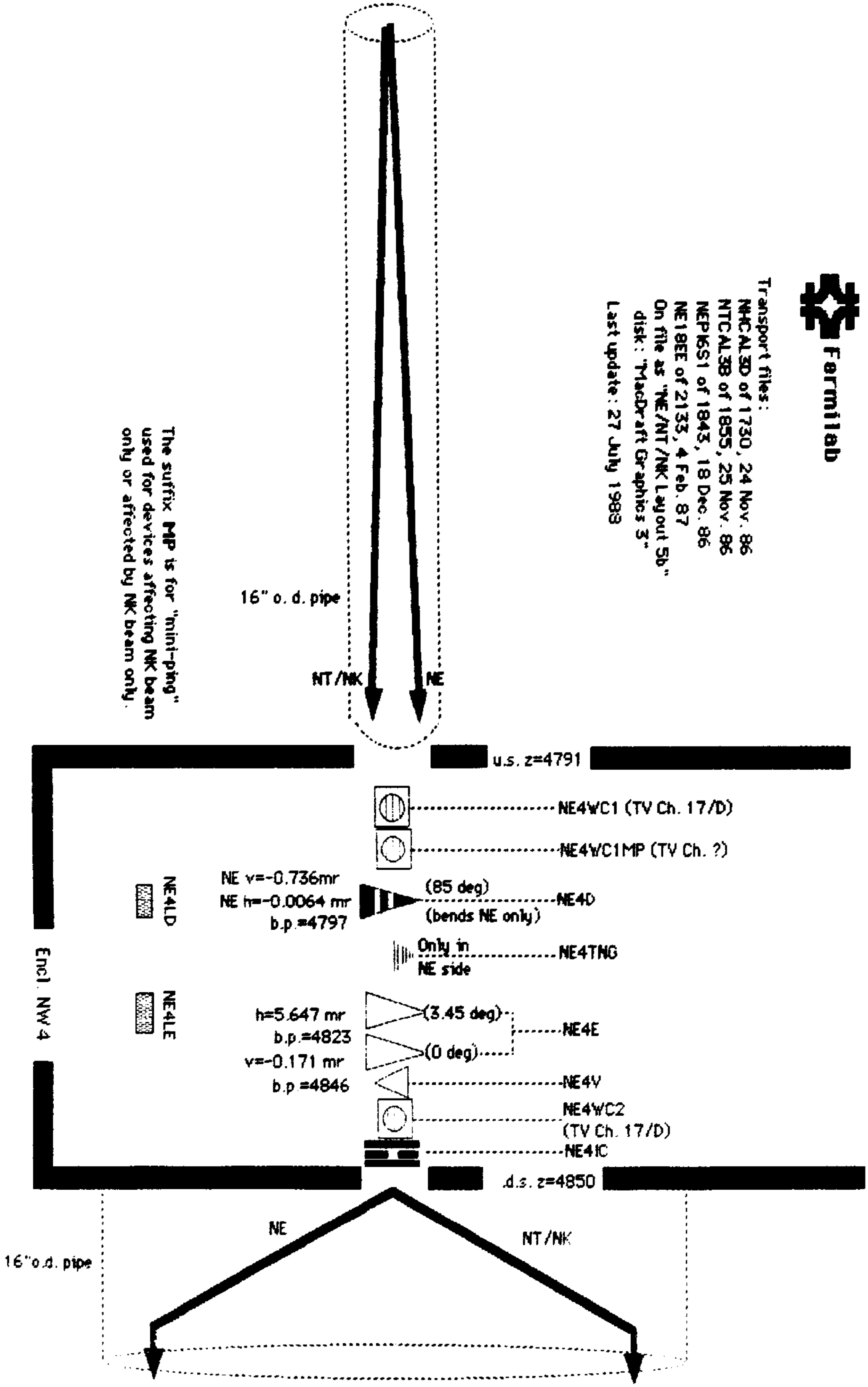
Halo file:
BCHAL03 of 1624, 14 June 88

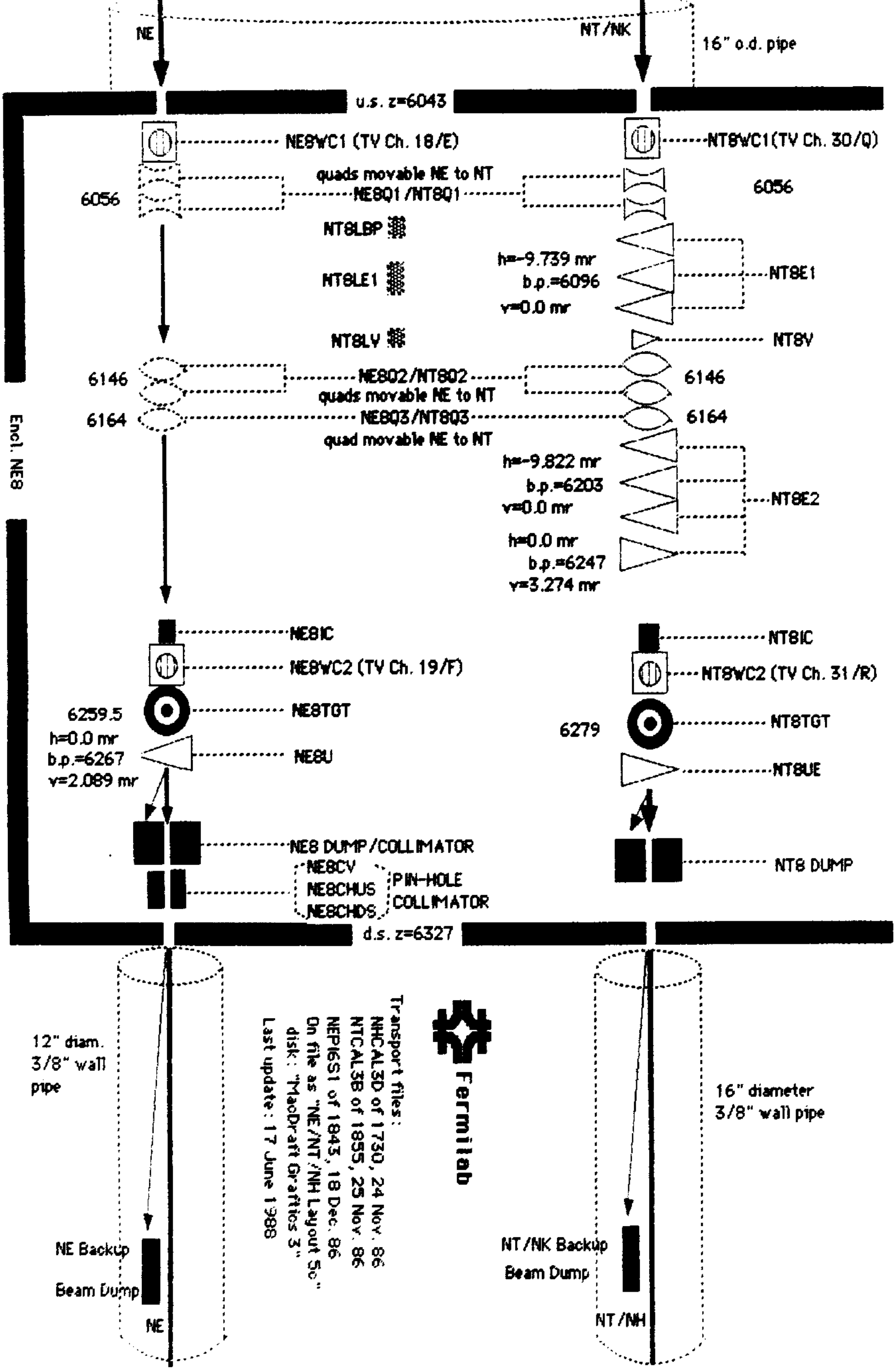
Septa remote H. V. control and status:
NE1SP12 (current)
NE1RDSP12 (voltage)
Motor drives: NE1MD1SP1, NE1MD1SP2
NE1MD2SP1, NE1MD2SP2
(Ref: Spires' memo of 3 March 1987)
NE1D1SP1A, NE1D1SP2A, NE1D2SP1A, NE1D2SP2A

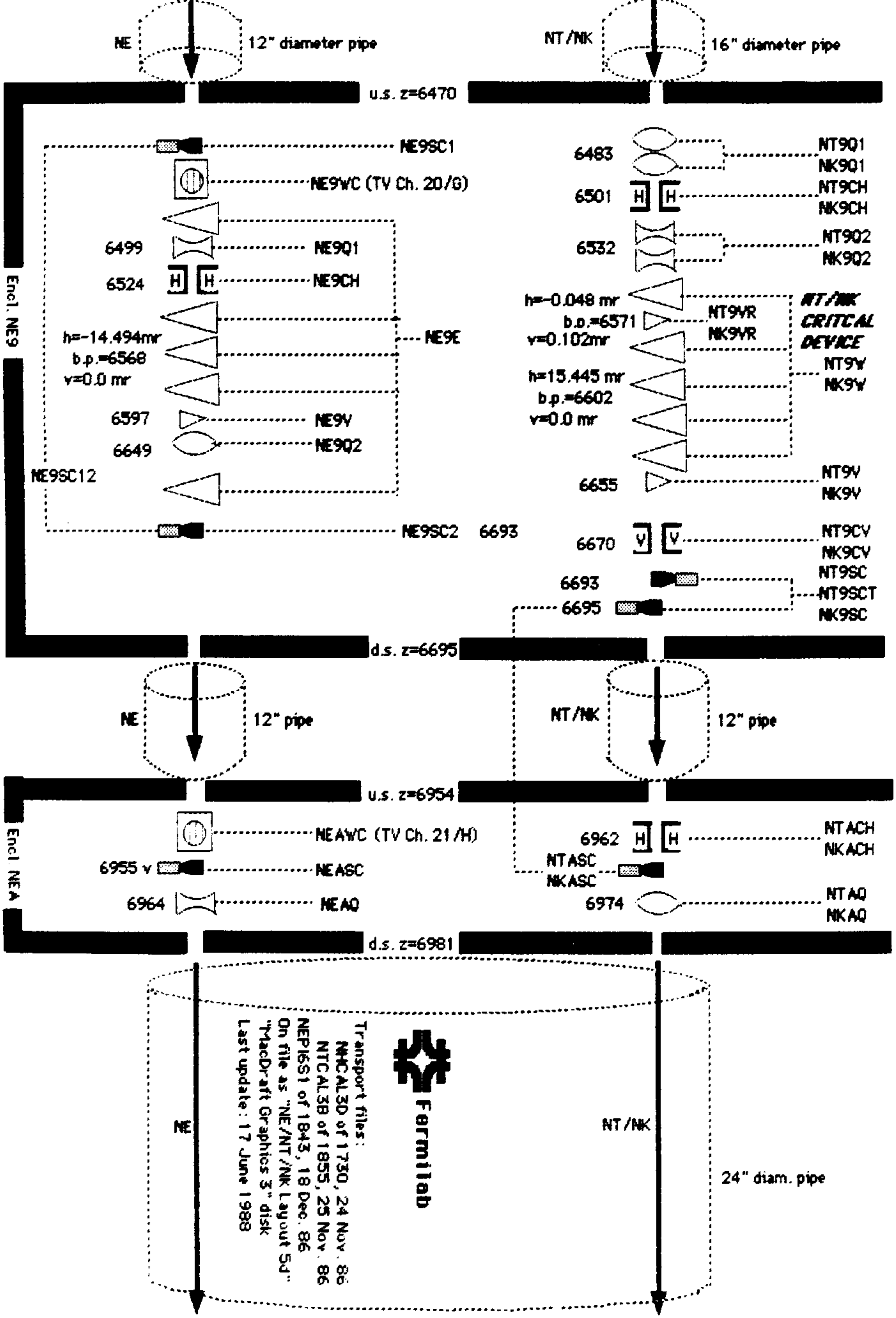


Septa Naming Conventions:
Vacuum readouts:
Cold cathode: NE1CC1SP, NE1CC2SP, NE1CC3SP
Pirani guages: NE1PG1SP, NE1PG2SP, NE1PG3SP
Vacuum valves: NE1VV1SP, NE1VV2SP
H. V. Power supplies: NE1HVSP1-2

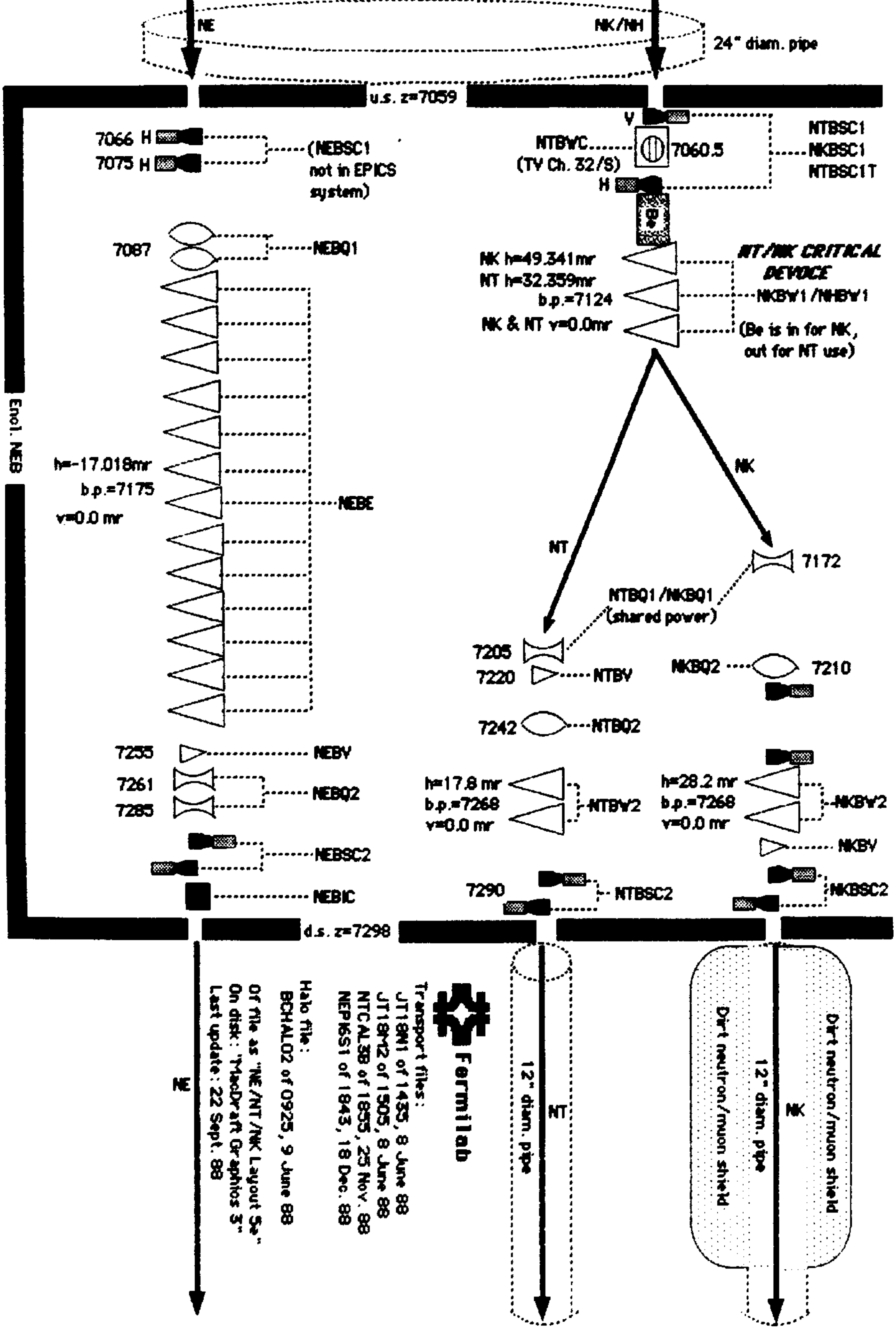
Note: the suffix MP stands for "mini-ping" of the NK beam


Fermilab
Transport files:
NHCAL3D of 1730, 24 Nov. 86
NTCAL3B of 1855, 25 Nov. 86
NEPI6S1 of 1843, 18 Dec. 86
NE18EE of 2133, 4 Feb. 87
On file as "NE/NT/NK Layout 5b"
disk: "MacDraft Graphics 3"
Last update: 27 July 1988
The suffix MP is for "mini-ping" used for devices affecting NK beam only or affected by NK beam only.
16" o. d. pipe
NT/NK
NE
u.s. z=4791
NE4WC1 (TV Ch. 17/D)
NE4WC1MP (TV Ch. ?)
NE v=-0.736mr
NE h=-0.0064 mr
b.p.=4797
(85 deg)
(bends NE only)
NE4D
NE4LD
Only in NE side
NE4TNG
Encl. NW4
NE4LE
h=5.647 mr
b.p.=4823
v=-0.171 mr
b.p.=4846
(3.45 deg)
(0 deg)
NE4E
NE4V
NE4WC2 (TV Ch. 17/D)
NE4IC
d.s. z=4850
NE
NT/NK
16"o.d. pipe

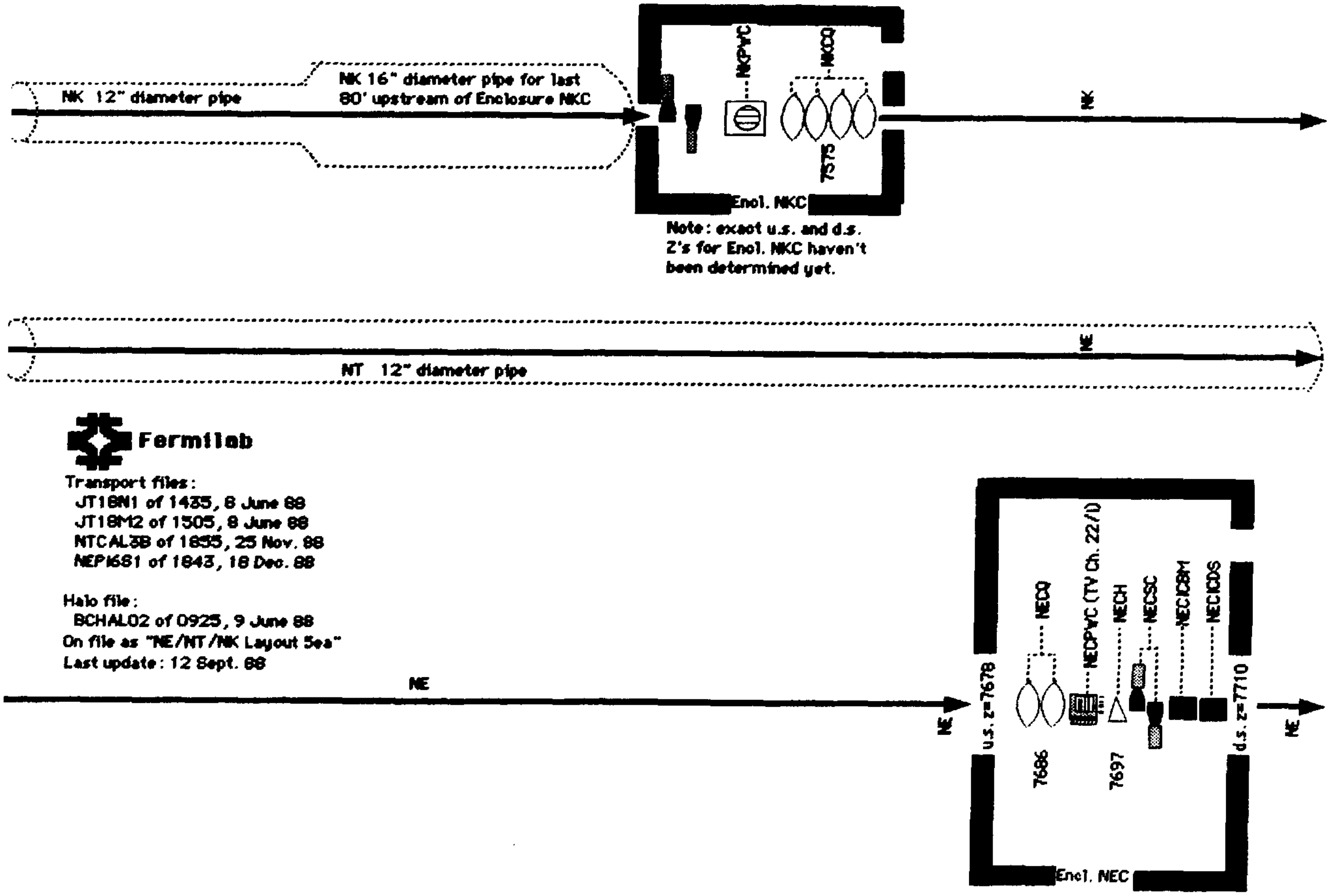

NE
NT/NK
16" o.d. pipe
u.s. z=6043
NE8WC1 (TV Ch. 18/E)
NT8WC1(TV Ch. 30/Q)
quads movable NE to NT
NE8Q1/NT8Q1
6056
6056
NT8LBP
NT8LE1
NT8LV
h=-9.739 mr
b.p.=6096
v=0.0 mr
NT8E1
NT8V
6146
NE8Q2/NT8Q2
quads movable NE to NT
6146
6164
NE8Q3/NT8Q3
quad movable NE to NT
6164
Encl. NE8
h=-9.822 mr
b.p.=6203
v=0.0 mr
NT8E2
h=0.0 mr
b.p.=6247
v=3.274 mr
NE8IC
NE8WC2 (TV Ch. 19/F)
NT8IC
NT8WC2 (TV Ch. 31/R)
6259.5
NE8TGT
6279
NT8TGT
h=0.0 mr
b.p.=6267
v=2.089 mr
NE8U
NT8UE
NE8 DUMP/COLLIMATOR
NT8 DUMP
NE8CV
NE8CHUS
NE8CHDS
PIN-HOLE
COLLIMATOR
d.s. z=6327
12" diam.
3/8" wall
pipe
Transport files:
NHCAL3D of 1730, 24 Nov. 86
NTCAL3B of 1855, 25 Nov. 86
NEPI6S1 of 1843, 18 Dec. 86
On file as "NE/NT/NH Layout 5c"
disk: "MacDraft Graffics 3"
Last update: 17 June 1988
Fermilab
16" diameter
3/8" wall pipe
NE Backup
Beam Dump
NE
NT/NK Backup
Beam Dump
NT/NH

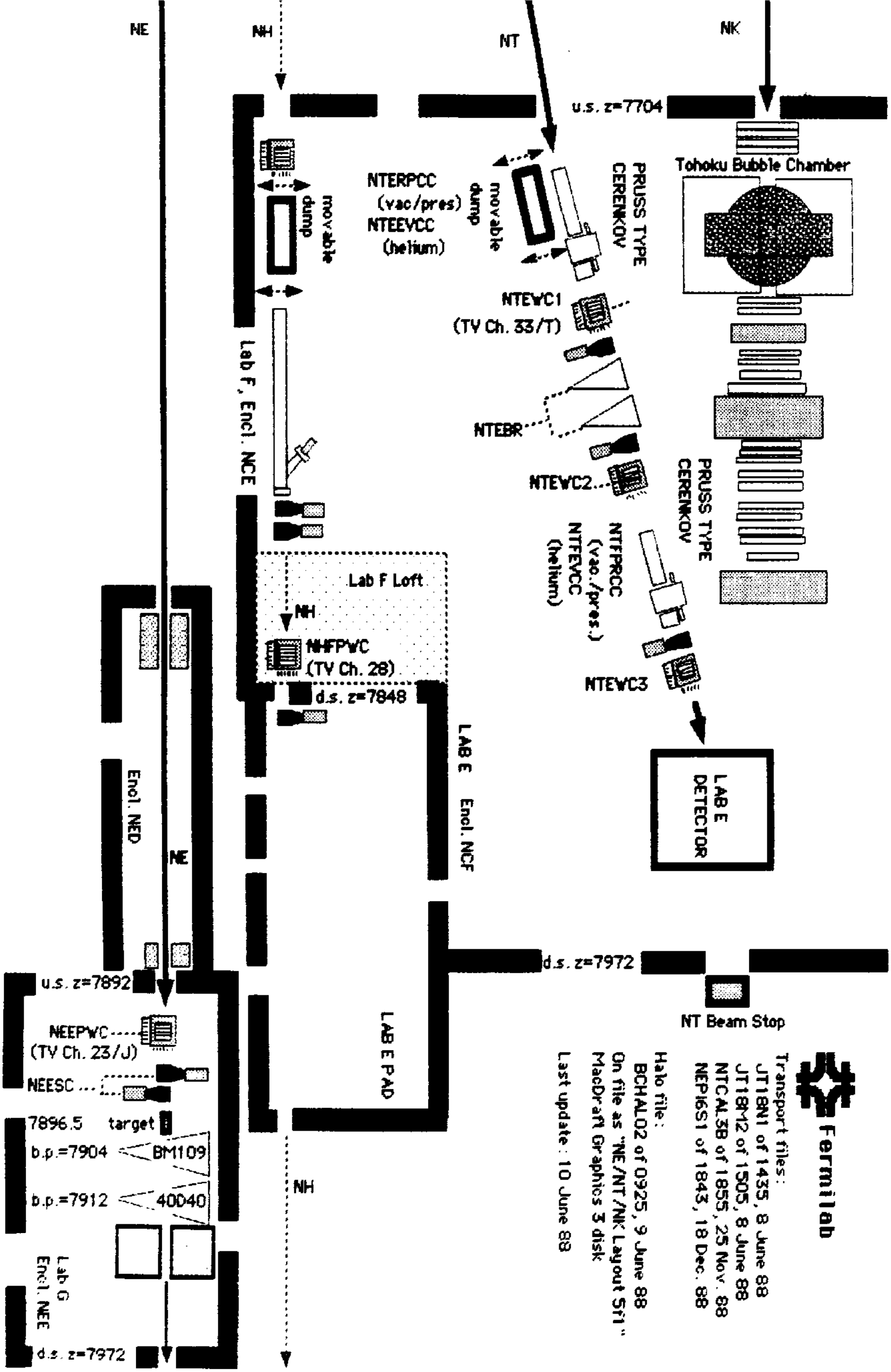


NE
12" diameter pipe
NT/NK
16" diameter pipe
u.s. z=6470
NE9SC1
NE9WC (TV Ch. 20/G)
6499
NE9Q1
6524
NE9CH
h=-14.494mr
b.p.=6568
v=0.0 mr
NE9E
6597
NE9V
6649
NE9Q2
NE9SC12
NE9SC2 6693
Encl. NE9
6483
NT9Q1
NK9Q1
6501
NT9CH
NK9CH
6532
NT9Q2
NK9Q2
h=-0.048 mr
b.p.=6571
v=0.102mr
NT9VR
NK9VR
NT/NK CRITCAL DEVICE
h=15.445 mr
b.p.=6602
v=0.0 mr
NT9W
NK9W
6655
NT9V
NK9V
6670
NT9CV
NK9CV
6693
6695
NT9SC
NT9SCT
NK9SC
d.s. z=6695
NE
12" pipe
NT/NK
12" pipe
u.s. z=6954
Encl. NEA
NEAWC (TV Ch. 21/H)
6955 v
NEASC
6964
NEAQ
6962
NTACH
NKACH
NTASC
NKASC
6974
NTAQ
NKAQ
d.s. z=6981
NE
NT/NK
24" diam. pipe
Fermilab
Transport files:
NHCAL3D of 1730, 24 Nov. 86
NTCAL3B of 1855, 25 Nov. 86
NEPI6S1 of 1843, 18 Dec. 86
On file as "NE/NT/NK Layout 5d"
"MacDraft Graphics 3" disk
Last update: 17 June 1988



NE
NK/NH
24" diam. pipe
u.s. z=7059
7066 H
7075 H
(NEBSC1
not in EPICS
system)
V
NTBWC
(TV Ch. 32/S)
7060.5
H
NTBSC1
NKBSC1
NTBSC1T
Be
7087
NEBQ1
NK h=49.341mr
NT h=32.359mr
b.p.=7124
NK & NT v=0.0mr
NT/NK CRITICAL DEVICE
NKBW1/NHBW1
(Be is in for NK,
out for NT use)
Encl. NEB
h=-17.018mr
b.p.=7175
v=0.0 mr
NEBE
NK
NT
7172
NTBQ1/NKBQ1
(shared power)
7205
7220
NTBV
NKBQ2
7210
7242
NTBQ2
7255
NEBV
7261
7285
NEBQ2
h=17.8 mr
b.p.=7268
v=0.0 mr
NTBW2
h=28.2 mr
b.p.=7268
v=0.0 mr
NKBW2
NKBV
NEBSC2
NEBIC
7290
NTBSC2
NKBSC2
d.s. z=7298
NE
Last update: 22 Sept. 88
On disk: "MacDraft Graphics 3"
Of file as "NE/NT/NK Layout 5e"
Halo file:
BCHALO2 of 0925, 9 June 88
Transport files:
JT18N1 of 1435, 8 June 88
JT18W2 of 1505, 8 June 88
NTCAL3B of 1855, 25 Nov. 88
NEP6S1 of 1843, 18 Dec. 88
Fermilab
12" diam. pipe
NT
Dirt neutron/muon shield
12" diam. pipe
NK
Dirt neutron/muon shield


NK 12" diameter pipe
NK 16" diameter pipe for last
80' upstream of Enclosure NKC
NKPWC
NKCQ
7575
NK
Encl. NKC
Note: exact u.s. and d.s.
Z's for Encl. NKC haven't
been determined yet.
NE
NT 12" diameter pipe
Fermilab
Transport files:
JT1BN1 of 1435, 8 June 88
JT1BM2 of 1505, 8 June 88
NTCAL3B of 1855, 25 Nov. 88
NEP1681 of 1843, 18 Dec. 88
Halo file:
BCHALO2 of 0925, 9 June 88
On file as "NE/NT/NK Layout 5ea"
Last update: 12 Sept. 88
NE
NE
u.s. z=7678
NECQ
7686
NECPWC (TV Ch. 22/I)
NECH
7697
NECSC
NECICBM
NECICDS
d.s. z=7710
NE
Encl. NEC


NE
NH
NT
NK
u.s. z=7704
Tohoku Bubble Chamber
PRUSS TYPE CERENKOV
movable dump
NTERPCC
(vac/pres)
NTEEVCC
(helium)
movable dump
NTEWC1
(TV Ch. 33/T)
NTEBR
NTEWC2
PRUSS TYPE CERENKOV
NTFPRCC
(vac./pres.)
NTFEVCC
(helium)
Lab F, Encl. NCE
Lab F Loft
NH
NHFPWC
(TV Ch. 28)
d.s. z=7848
NTEWC3
LAB E DETECTOR
LAB E
Encl. NCF
Encl. NED
NE
d.s. z=7972
NT Beam Stop
u.s. z=7892
NEEPWC
(TV Ch. 23/J)
NEESC
LAB E PAD
7896.5
target
b.p.=7904
BM109
b.p.=7912
40D40
NH
Lab G
Encl. NEE
d.s. z=7972
Fermilab
Transport files:
JT18N1 of 1435, 8 June 88
JT18M12 of 1505, 8 June 88
NTCAL3B of 1855, 25 Nov. 88
NEP16S1 of 1843, 18 Dec. 88
Halo file:
BCHAL02 of 0925, 9 June 88
On file as "NE/NT/NK Layout 5i1"
MacDraft Graphics 3 disk
Last update: 10 June 88

```
HISTOGRAM NO.  3                                                    DATE 88/07/19.                        TIME 03.34.03.
HORIZONTAL AXIS...  X      IN IN      FOR MU     AT      1462.579 FT    (POSITION NO.  94)
VERTICAL AXIS...    Y      IN IN      FOR MU     AT      1462.579 FT    (POSITION NO.  94)
FLAGS =  CMU28

                              -1.00          .00         1.00
                                +-----------+-----------+ SUMS
     -9.843 TO    -8.807  I       111   22             I    7
     -8.807 TO    -7.771  I      11111   371 1         I   17
     -7.771 TO    -6.735  I      1 23 337432           I   28
     -6.735 TO    -5.699  I      1 21453452            I   27
     -5.699 TO    -4.662  I       11312676E3           I   44
     -4.662 TO    -3.626  I       1221256EC2           I   47
     -3.626 TO    -2.590  I       42 3 698621          I   44
     -2.590 TO    -1.554  I      1446448GE8A3          I   82
     -1.554 TO     -.518  I      1222198CH842          I   68
      -.518 TO      .518  +       1335 5DDE22          +   61
       .518 TO     1.554  I      21 2257DA921          I   54
      1.554 TO     2.590  I      1314559FJ981          I   80
      2.590 TO     3.626  I      12 2357AF642          I   57
      3.626 TO     4.662  I      11122328A9D           I   52
      4.662 TO     5.699  I       251 5699352          I   47
      5.699 TO     6.735  I      3211 46725 2          I   33
      6.735 TO     7.771  I      1  211195432          I   29
      7.771 TO     8.807  I       1 1145452            I   23
      8.807 TO     9.843  I      1     33131           I   12
                                +-----------+-----------+ SUMS
                          S                            S
                          U             111            U
                          M      122335956161          M
                          S      578747277819          S

           UNDER     IN    OVER
UNDER        0        3      0             HMEAN =         .12594 IN          SIGMAH =        .24648 IN
IN           0      812      0             VMEAN =         .24722 IN          SIGMAV =       4.46286 IN
OVER         0        4      0             CORRELATION =    .04377

TOTAL NUMBER OF PARTICLES CONSIDERED       819
```

Scatter plot of μ's from π^+ at the Tohoku Bubble Chamber which are within the vertical stripe 3 cm wide and 60 cm high (full width)

1 entry reprsents 14.59 muons or halo muons/1 x 10^{11} protons on target
200 GeV/c π^+ upstream of the Be filter
21.5 feet of Be filter located upstream of NKBW1-1 dipole
196 GeV/c μ^+ downstream of the Be filter
HALO file used: BCHAL04 of 1723, 18 July 1988

```
HISTOGRAM NO.   4
HORIZONTAL AXIS...  X      IN IN      FOR HALO  AT        784.156 FT     (POSITION NO.  47)      TIME 03.34.03.
VERTICAL AXIS...    Y      IN IN      FOR HALO  AT        784.156 FT     (POSITION NO.  47)
FLAGS =   C500C                                        DATE 88/07/19.

                          -6.00      -1.00      4.00
                           +----------+----------+----+  SUMS
 -2.500 TO     -2.000 I                     1        I     1
 -2.000 TO     -1.500 I                1             I     1
 -1.500 TO     -1.000 I          1 112               I     5
 -1.000 TO      -.500 I      1   1 611      11   1 1 I    14
  -.500 TO       .000 I     1 415HLBEF911111         I   103
   .000 TO       .500 I     1 135EEDBG84             I    90
   .500 TO      1.000 I       221  2  2    2         I    11
  1.000 TO      1.500 I       1 1     1    1    1    I     5
  1.500 TO      2.000 I               1        1     I     2
  2.000 TO      2.500 +                     1 2      +     3
                           +----------+----------+----+  SUMS
                           S                          S
                           U                          U
                           M         1342331          M
                           S    218641462277233312 1  S

         UNDER      IN    OVER
UNDER      0         1      0                HMEAN =          .12864 IN              SIGMAH =        3.61433 IN
IN         0       235      1                VMEAN =         -.00200 IN              SIGMAV =         .67967 IN
OVER       0         1      0                CORRELATION =     .16623

TOTAL NUMBER OF PARTICLES CONSIDERED      238
```

Scatter plot of halo μ's from π^+ at the upstream end of Enclosure NEB, just upstream of the Be filter.

1 entry reprsents 14.59 muons or halo muons/1 x 10^{11} protons on target
200 GeV/c π^+ upstream of the Be filter
21.5 feet of Be filter located upstream of NKBW1-1 dipole
196 GeV/c μ^+ downstream of the Be filter
HALO file used: BCHAL04 of 1723, 18 July 1988

```
HISTOGRAM NO.  7                                            DATE 88/07/19.                                  TIME 03.34.03.
HORIZONTAL AXIS...  X      IN IN     FOR HALO  AT      1021.175 FT    (POSITION NO.  67)
VERTICAL AXIS...    Y      IN IN     FOR HALO  AT      1021.175 FT    (POSITION NO.  67)
FLAGS =  TOHA

                        -5.00     5.00      15.00     25.00     35.00     45.00
                          +---------+---------+---------+---------+---------+ SUMS
  -5.000 TO   -4.000 I    1                    1 1        1    1         I    5
  -4.000 TO   -3.000 I    11 21               12111                      I   11
  -3.000 TO   -2.000 I      1421             3 252331 2      2           I   31
  -2.000 TO   -1.000 I1 129312               322532 3   1                I   40
  -1.000 TO     .000 I  18NV8121            1 1332442  1             1   I   97
    .000 TO    1.000 I  5ITIK52   1           1146 442                   I  120
   1.000 TO    2.000 I  1222 1 111            51723241  1   1            I   38
   2.000 TO    3.000 I     23                 3321 11  2                 I   18
   3.000 TO    4.000 I     4                  1111  2  2                 I   12
   4.000 TO    5.000 +      2                  2    11 1          1      +    8
   5.000 TO    6.000 I                      1                            I    1
   6.000 TO    7.000 I                          1 1                      I    2
   7.000 TO    8.000 I                                                   I
                     +---------+---------+---------+---------+---------+ SUMS
                     S                                                   S
                     U                                                   U
                     M    36641               1121111                    M
                     S1 8241025212          17489944842611 12 1  1  1    S

         UNDER     IN    OVER
UNDER      0        8      0               HMEAN =          9.46879 IN                SIGMAH =          11.23438 IN
IN         0      383      0               VMEAN =           .00364 IN                SIGMAV =           2.56274 IN
OVER       0        1      0               CORRELATION =      .00181

TOTAL NUMBER OF PARTICLES CONSIDERED        392
```

Scatter plot of halo μ's from π^+ at the downstream end of Enclosure NEB.

1 entry reprsents 14.59 muons or halo muons/1 x 10^{11} protons on target
200 GeV/c π^+ upstream of the Be filter
21.5 feet of Be filter located upstream of NKBV1-1 dipole
196 GeV/c μ^+ downstream of the Be filter
HALO file used: **BCHALO4 of 1723, 18 July 1988**

```
HISTOGRAM NO.  27                                                    DATE 88/07/19.                         TIME 03.34.03.
DISTRIBUTION OF     P      IN GEV/C FOR MU     AT      1462.579 FT     (POSITION NO.   94)
FLAGS =   CMU28

SCALE FACTOR... 1 X =    10 ENTRIES.

LESS THAN         180.000        0

    180.000 TO    181.000        0
    181.000 TO    182.000        0
    182.000 TO    183.000        0
    183.000 TO    184.000        0
    184.000 TO    185.000        0
    185.000 TO    186.000        0
    186.000 TO    187.000        0
    187.000 TO    188.000        0
    188.000 TO    189.000        0
    189.000 TO    190.000        0
    190.000 TO    191.000        9   9
    191.000 TO    192.000       21   XX1
    192.000 TO    193.000       24   XX4
    193.000 TO    194.000       51   XXXXX1
    194.000 TO    195.000       47   XXXX7
    195.000 TO    196.000       87   XXXXXXXX7
    196.000 TO    197.000      130   XXXXXXXXXIXXX
    197.000 TO    198.000      155   XXXXXXXXXIXXXXX5
    198.000 TO    199.000      135   XXXXXXXXXIXXX5
    199.000 TO    200.000       98   XXXXXXXXX8
    200.000 TO    201.000       45   XXXX5
    201.000 TO    202.000       15   X5
    202.000 TO    203.000        2   2
    203.000 TO    204.000        0
    204.000 TO    205.000        0

GREATER THAN      205.000        0

HMEAN =    196.97521 GEV/C    R.M.S. HALF WIDTH =      2.33229 GEV/C

TOTAL NUMBER OF PARTICLES CONSIDERED        819
```

Histogram of μ's from π^+ at the Tohoku Bubble Chamber which are within the vertical stripe 3 cm wide and 60 cm high (full width).

1 entry reprsents 14.59 muons or halo muons/1 x 10^{11} protons on target
200 GeV/c π^+ upstream of the Be filter
21.5 feet of Be filter located upstream of NKBV1-1 dipole
196 GeV/c μ^+ downstream of the Be filter
HALO file used: BCHAL04 of 1723, 18 July 1988

```
                                                              DATE 88/07/19.                          TIME 03.34.03.
HISTOGRAM NO.  29
HORIZONTAL AXIS...  X      IN IN     FOR MU     AT      1462.579 FT     (POSITION NO.   94)
VERTICAL AXIS...    Y      IN IN     FOR MU     AT      1462.579 FT     (POSITION NO.   94)
                       -19.69    -14.64    -9.59     -4.54      .50      5.55     10.60     15.65
                          +---------+---------+---------+---------+---------+---------+---------+---------+ SUMS
                          I                                      34                                       I    7
 -9.843 TO   -8.807       I                                    1481                                       I   17
 -8.807 TO   -7.771       I                                    18J1                                       I   29
 -7.771 TO   -6.735       I                                     1DE                                       I   28
 -6.735 TO   -5.699       I                                     18$                                       I   45
 -5.699 TO   -4.662       I                                    158$                                       I   53
 -4.662 TO   -3.626       I                                   359Y2                                       I   53
 -3.626 TO   -2.590       I                                   34M$3                                       I   88
 -2.590 TO   -1.554       I                                   22G$3                                       I   72
 -1.554 TO    -.518       I                                    2C$3                                       +   64
  -.518 TO     .518       +                                     4A$                                       I   56
   .518 TO    1.554       I                                    32J$                                       I   85
  1.554 TO    2.590       I                                   16C$1                                       I   63
  2.590 TO    3.626       I                                   249$1                                       I   58
  3.626 TO    4.662       I                                    2DW2                                       I   49
  4.662 TO    5.699       I                                    48K2                                       I   34
  5.699 TO    6.735       I                                    24M2                                       I   30
  6.735 TO    7.771       I                                    127G                                       I   26
  7.771 TO    8.807       I                                    1 81                                       I   13
  8.807 TO    9.843       I                                                                               + SUMS
                          +---------+---------+---------+---------+---------+---------+---------+---------S
                          S                                      15                                       U
                          U                                   14892                                       M
                          M                                   69582                                       S
                          S

        UNDER     IN     OVER
UNDER     0        3       0           HMEAN  =          .06873 IN          SIGMAH =        .34857 IN
IN        0      870       0           VMEAN  =          .25972 IN          SIGMAV =       4.43279 IN
OVER      0        4       0           CORRELATION =     .02491

TOTAL NUMBER OF PARTICLES CONSIDERED         877
```

Scatter plot of μ's from π^+ at the Tohoku Bubble Chamber which are within the bubble chamber.

1 entry reprsents 14.59 muons or halo muons/1×10^{11} protons on target
200 GeV/c π^+ upstream of the Be filter
21.5 feet of Be filter located upstream of NKBW1-1 dipole
196 GeV/c μ^+ downstream of the Be filter
HALO file used: BCHAL04 of 1723, 18 July 1988

```
                                                                DATE 88/07/19.                        TIME 03.34.03.
HISTOGRAM NO. 34
HORIZONTAL AXIS...  X       IN IN     FOR HALO  AT       1462.579 FT     (POSITION NO.  94)
VERTICAL AXIS...    Y       IN IN     FOR HALO  AT       1462.579 FT     (POSITION NO.  94)
FLAGS =  TOHA

                        -19.69      -9.59        .50       10.60
                          +----------+----------+----------+----------+ SUMS
 -9.843 TO   -8.807  I  1 3 1 1 1     1114423121                    11I  29
 -8.807 TO   -7.771  I    1 1  4       11  423          1            1I  18
 -7.771 TO   -6.735  I          1 2     22 211      1               1I  13
 -6.735 TO   -5.699  I  1 1             1 11      1     1         1111I  11
 -5.699 TO   -4.662  I1 1      112 1    21    1     1        11      1I  15
 -4.662 TO   -3.626  I 1  1      1   1 1 1    21           1 2       1I  13
 -3.626 TO   -2.590  I   11   1   112 11111 32          1     1     11I  21
 -2.590 TO   -1.554  I 1  2121 113 2 2 1 11      11      1    1     11I  25
 -1.554 TO    -.518  I1    1 12      2     122 11    2 2 3 2122    1 1I  30
  -.518 TO     .518  + 11   3 1 41111123 27A 424213 1 32 22 1        +  66
   .518 TO    1.554  I  1 4112      311132    1121 2     21111 1 141I  39
  1.554 TO    2.590  I 1121  2 11 12 132  2 1             1    2     I  24
  2.590 TO    3.626  I1    21 12         1   1   13          21 11 1I  19
  3.626 TO    4.662  I    1      111 11  1 1 11112          212      I  19
  4.662 TO    5.699  I  1     11 1 2     2     1  1          21 1   1 I  15
  5.699 TO    6.735  I               1    1 1       11   1      1   1 I   8
  6.735 TO    7.771  I    11 11         1121111 1              11    I  15
  7.771 TO    8.807  I        1           3 111  1 1         123      I  15
  8.807 TO    9.843  I 1  2 1      1    12262323 1 1     1      111 11I  33
                          +----------+----------+----------+----------+ SUMS
                          S                                           S
                          U                                           U
                          M     1   1 1 1    1222311 11     11       1M
                          S34779982759486876231898225  601889589825

        UNDER      IN     OVER
UNDER      0        0       0           HMEAN =           -.47232 IN                   SIGMAH =        9.93222 IN
IN         0      428       0           VMEAN =            .06014 IN                   SIGMAV =        5.26441 IN
OVER       0        0       0           CORRELATION =      .07828

TOTAL NUMBER OF PARTICLES CONSIDERED        428
```

Scatter plot of halo μ's from π^+ at the Tohoku Bubble Chamber which are within the bubble chamber.

1 entry reprsents 14.59 muons or halo muons/1 x 10^{11} protons on target
200 GeV/c π^+ upstream of the Be filter
21.5 feet of Be filter located upstream of NKBW1-1 dipole
196 GeV/c μ^+ downstream of the Be filter
HALO file used: BCHALO4 of 1723, 18 July 1988

```
HISTOGRAM NO. 35                                        DATE 88/07/19.                    TIME 03.34.03.
DISTRIBUTION OF    P      IN GEV/C FOR HALO  AT      1462.579 FT    (POSITION NO.  94)
FLAGS =  TOHA

SCALE FACTOR... 1 X =     1 ENTRIES.

LESS THAN              .000          0
     .000 TO      5.000          0
    5.000 TO     10.000          1  X
   10.000 TO     15.000          0
   15.000 TO     20.000          1  X
   20.000 TO     25.000          1  X
   25.000 TO     30.000          0
   30.000 TO     35.000          0
   35.000 TO     40.000          0
   40.000 TO     45.000          1  X
   45.000 TO     50.000          0
   50.000 TO     55.000          0
   55.000 TO     60.000          0
   60.000 TO     65.000          2  XX
   65.000 TO     70.000          0
   70.000 TO     75.000          3  XXX
   75.000 TO     80.000          2  XX
   80.000 TO     85.000          4  XXXX
   85.000 TO     90.000          5  XXXXX
   90.000 TO     95.000          4  XXXX
   95.000 TO    100.000         10  XXXXXXXXXI
  100.000 TO    105.000          7  XXXXXXX
  105.000 TO    110.000          8  XXXXXXXX
  110.000 TO    115.000          4  XXXX
  115.000 TO    120.000         15  XXXXXXXXXIXXXXX
  120.000 TO    125.000         18  XXXXXXXXXIXXXXXXXX
  125.000 TO    130.000         31  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIX
  130.000 TO    135.000         20  XXXXXXXXXIXXXXXXXXXI
  135.000 TO    140.000         20  XXXXXXXXXIXXXXXXXXXI
  140.000 TO    145.000         17  XXXXXXXXXIXXXXXXX
  145.000 TO    150.000         15  XXXXXXXXXIXXXXX
  150.000 TO    155.000         10  XXXXXXXXXI
  155.000 TO    160.000          5  XXXXX
  160.000 TO    165.000         10  XXXXXXXXXI
  165.000 TO    170.000         11  XXXXXXXXXIX
  170.000 TO    175.000         21  XXXXXXXXXIXXXXXXXXXIX
  175.000 TO    180.000         15  XXXXXXXXXIXXXXX
  180.000 TO    185.000         23  XXXXXXXXXIXXXXXXXXXIXXX
  185.000 TO    190.000         30  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXI
  190.000 TO    195.000         38  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXX
  195.000 TO    200.000         52  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXX
  200.000 TO    205.000         23  XXXXXXXXXIXXXXXXXXXIXXX
  205.000 TO    210.000          1  X
  210.000 TO    215.000          0
  215.000 TO    220.000          0
  220.000 TO    225.000          0
  225.000 TO    230.000          0
  230.000 TO    235.000          0
  235.000 TO    240.000          0
  240.000 TO    245.000          0
  245.000 TO    250.000          0

GREATER THAN    250.000          0

HMEAN =   156.62587 GEV/C   R.M.S. HALF WIDTH =    37.67131 GEV/C

TOTAL NUMBER OF PARTICLES CONSIDERED       428
```

Histogram of halo μ's from π^+ at the Tohoku Bubble Chamber which are within the bubble chamber.

1 entry reprsents 14.59 muons or halo muons/1 x 10^{11} protons on target
200 GeV/c π^+ upstream of the Be filter
21.5 feet of Be filter located upstream of NKBV1-1 dipole
196 GeV/c μ^+ downstream of the Be filter
HALO file used: **BCHAL04 of 1723, 18 July 1988**

```
HISTOGRAM NO.  36                                          DATE 88/07/19.                              TIME 03.34.03.
HORIZONTAL AXIS...   X        IN IN     FOR HALO  AT     1462.579 FT     (POSITION NO.  94)
VERTICAL AXIS...     Y        IN IN     FOR HALO  AT     1462.579 FT     (POSITION NO.  94)
FLAGS =  HA200

                              -100.00        .00     100.00
                                 +----------+----------+ SUMS
 -100.000 TO     -90.000 IE6AB6B3A25131 33 1 1I   91
  -90.000 TO     -80.000 I9EB4755936363441121 I   98
  -80.000 TO     -70.000 IFGB8C6FB8674362131  I  135
  -70.000 TO     -60.000 ICCBAFICEABA5B39221 2I  170
  -60.000 TO     -50.000 IJDSEMLECHL85BE634132I  238
  -50.000 TO     -40.000 ICKMLTIHMILJBA8575231I  271
  -40.000 TO     -30.000 ILVLUTOQV$$UWQH8A5C52I  446
  -30.000 TO     -20.000 IM$$$$$$$$$$$ZP8B7551I  810
  -20.000 TO     -10.000 I$$$$$$$$$$$Y$WOE8B6 I  981
  -10.000 TO        .000 +$$$$$$$$$$$Z$$$HB674+  937
     .000 TO      10.000 I$$$$$$$U$$$$$$TCCA4 I  945
   10.000 TO      20.000 I$$$$$$$$$$$$$$HJB684I 1029
   20.000 TO      30.000 I$$$$T$$$$$$$$L864512I  755
   30.000 TO      40.000 IORKRQVVV$T$YCE774332I  407
   40.000 TO      50.000 IAFJMLSJQQTLD87443432I  284
   50.000 TO      60.000 IKDIEJGIHGF89984634  I  220
   60.000 TO      70.000 IBEGGDF7C7E635575  23I  161
   70.000 TO      80.000 I978DDA48658544322112I  124
   80.000 TO      90.000 IA9699845612744214  1I   92
   90.000 TO     100.000 +965745638344213 1  1+   72
                         +----------+----------+ SUMS
                         S                    S
                         U4555565569643311    U
                         M62241101909188838753M
                         S58148899452892917520S

        UNDER      IN    OVER
UNDER      0        0      0               HMEAN =        -24.07037 IN            SIGMAH =        43.14331 IN
IN         0     8266      0               VMEAN =          -.73045 IN            SIGMAV =        35.96733 IN
OVER       0        0      0               CORRELATION =     .00861

TOTAL NUMBER OF PARTICLES CONSIDERED       8266
```

Scatter plot of halo μ's from π^+ at the Tohoku Bubble Chamber which are within ±100 inches of the center of the Tohoku Bubble Chamber.

1 entry reprsents 14.59 muons or halo muons/1 x 10^{11} protons on target
200 GeV/c π^+ upstream of the Be filter
21.5 feet of Be filter located upstream of NKBW1-1 dipole
196 GeV/c μ^+ downstream of the Be filter
HALO file used: **BCHAL04 of 1723, 18 July 1988**

```
ISTOGRAM NO. 38                                             DATE 88/07/19.                         TIME 03.34.03.
ISTRIBUTION OF    P      IN GEV/C FOR HALO  AT      1462.579 FT    (POSITION NO.  94)
.AGS =  HA200

:ALE FACTOR... 1 X =   10 ENTRIES.

ESS THAN              .000         0

    .000 TO          5.000        32  XXX2
   5.000 TO         10.000        27  XX7
  10.000 TO         15.000        44  XXXX4
  15.000 TO         20.000        58  XXXXX8
  20.000 TO         25.000        81  XXXXXXXX1
  25.000 TO         30.000        70  XXXXXXX
  30.000 TO         35.000        84  XXXXXXXX4
  35.000 TO         40.000       113  XXXXXXXXXIX3
  40.000 TO         45.000       123  XXXXXXXXXIXX3
  45.000 TO         50.000       146  XXXXXXXXXIXXXX6
  50.000 TO         55.000       142  XXXXXXXXXIXXXX2
  55.000 TO         60.000       189  XXXXXXXXXIXXXXXXXX9
  60.000 TO         65.000       217  XXXXXXXXXIXXXXXXXXXIX7
  65.000 TO         70.000       220  XXXXXXXXXIXXXXXXXXXIXX
  70.000 TO         75.000       237  XXXXXXXXXIXXXXXXXXXIXXX7
  75.000 TO         80.000       288  XXXXXXXXXIXXXXXXXXXIXXXXXXXX8
  80.000 TO         85.000       287  XXXXXXXXXIXXXXXXXXXIXXXXXXXX7
  85.000 TO         90.000       300  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXI
  90.000 TO         95.000       297  XXXXXXXXXIXXXXXXXXXIXXXXXXXXX7
  95.000 TO        100.000       350  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXX
 100.000 TO        105.000       324  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXX4
 105.000 TO        110.000       385  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXX5
 110.000 TO        115.000       383  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXX3
 115.000 TO        120.000       391  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXX1
 120.000 TO        125.000       451  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXX1
 125.000 TO        130.000       434  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXX4
 130.000 TO        135.000       434  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXX4
 135.000 TO        140.000       424  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXX4
 140.000 TO        145.000       380  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXX
 145.000 TO        150.000       305  XXXXXXXXXIXXXXXXXXXIXXXXXXXXXI5
 150.000 TO        155.000       158  XXXXXXXXXIXXXXX8
 155.000 TO        160.000       109  XXXXXXXXXI9
 160.000 TO        165.000       109  XXXXXXXXXI9
 165.000 TO        170.000       102  XXXXXXXXXI2
 170.000 TO        175.000        89  XXXXXXXX9
 175.000 TO        180.000        76  XXXXXXX6
 180.000 TO        185.000        60  XXXXXX
 185.000 TO        190.000        96  XXXXXXXXX6
 190.000 TO        195.000       101  XXXXXXXXXI1
 195.000 TO        200.000       114  XXXXXXXXXIX4
 200.000 TO        205.000        35  XXX5
 205.000 TO        210.000         1  1
 210.000 TO        215.000         0
 215.000 TO        220.000         0
 220.000 TO        225.000         0
 225.000 TO        230.000         0
 230.000 TO        235.000         0
 235.000 TO        240.000         0
 240.000 TO        245.000         0
 245.000 TO        250.000         0

GREATER THAN        250.000        0

HMEAN =   108.24866 GEV/C   R.M.S. HALF WIDTH =    41.34867 GEV/C
TOTAL NUMBER OF PARTICLES CONSIDERED       8266
```

Histogram of halo μ's from π^+ at the Tohoku Bubble Chamber which are within ± 100 inches of the center of the Tohoku Bubble Chamber.

1 entry reprsents 14.59 muons or halo muons/1×10^{11} protons on target
200 GeV/c π^+ upstream of the Be filter
21.5 feet of Be filter located upstream of NKBW1-1 dipole
196 GeV/c μ^+ downstream of the Be filter
HALO file used: **BCHAL04 of 1723, 18 July 1988**

```
HISTOGRAM NO.  41                                        DATE 88/07/19.                    TIME 03.34.03.
POPULATION OF HALO  AS A FUNCTION OF Z IN FT
FLAGS =  TOHA

SCALE FACTOR... 1 X =   10 ENTRIES.

        .000      0
      50.000      0
     100.000      0
     150.000      0
     200.000      1   1
     250.000      2   2
     300.000     56   XXXXX6
     350.000     56   XXXXX6
     400.000     58   XXXXX8
     450.000     58   XXXXX8
     500.000     58   XXXXX8
     550.000     59   XXXXX9
     600.000     59   XXXXX9
     650.000     59   XXXXX9
     700.000    258   XXXXXXXXXIXXXXXXXXXIXXXXX8
     750.000    258   XXXXXXXXXIXXXXXXXXXIXXXXX8
     800.000    258   XXXXXXXXXIXXXXXXXXXIXXXXX8
     850.000    293   XXXXXXXXXIXXXXXXXXXIXXXXXXXXX3
     900.000    368   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXX8
     950.000    375   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXX5
    1000.000    392   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXX2
    1050.000    392   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXX2
    1100.000    392   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXX2
    1150.000    392   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXX2
    1200.000    392   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXX2
    1250.000    392   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXX2
    1300.000    427   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXX7
    1350.000    428   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXX8
    1400.000    428   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXX8
    1450.000    426   XXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXXXXXXXXXIXX8
    1500.000      0

TOTAL NUMBER OF PARTICLES CONSIDERED        428
```

Histogram of halo μ's from π^+ which reach the Tohoku Bubble Chamber as a function of the distance in feet from the target. The histogram shows integrated halo μ's. Note: Z = 250 to 300 feet is the location of the upstream end of Enclosure NE9 with quads, a trim and dipoles. The Be filter starts 790.646 feet from the target at the upstream end of Enclosure NEB. Enclosure NEB continues on to Z of about 1020 feet with dipoles, quads, more dipoles and a trim. The final quad string spans a Z from about 1288 to 1306.

1 entry reprsents 14.59 muons or halo muons/1×10^{11} protons on target
200 GeV/c π^+ upstream of the Be filter
21.5 feet of Be filter located upstream of NKBW1-1 dipole
196 GeV/c μ^+ downstream of the Be filter
HALO file used: BCHAL04 of 1723, 18 July 1988